National Energy Technology Laboratory

Greenhouse Gas Emission Reductions
and Natural Gas Vehicles:

A Resource Guide on Technology
Options and Project Development

Prepared by:
Science Applications International Corporation (SAIC)

June 2001

National Energy Technology Laboratory

Greenhouse Gas Emission Reductions and Natural Gas Vehicles:

A Resource Guide on Technology Options and Project Development

Prepared by:
Science Applications International Corporation (SAIC)
Climate Change Services Practice
With contributions from: Sarah Billups, Vivianne Couts, Julie Doherty, Jette Findsen, Laura Gehlin, Chris Mahoney, Michael Mondshine

Prepared for:
National Energy Technology Laboratory (NETL)
626 Cochrans Mill Road
Pittsburgh, PA 15236

June 2001

Acknowledgements

The Greenhouse Gas Emission Reductions and Natural Gas Vehicles: A Resource Guide on Technology Options and Project Development was developed as a team effort in follow-up to the May 2000 training session at the 6th National Clean Cities Conference in San Diego, California on the Development of Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies. Contributions were made by James Ekmann, George Lee, Charlie Drummond, Eric Bell, and Daniel Cillo of the National Energy Technology Laboratory (NETL) as well as Jette Findsen, Julie Doherty, Laura Gehlin, Chris Minucci, Michael Mondshine, Chris Mahoney, Sarah Billups, and Vivianne Couts of Science Applications International Corporation (SAIC). The authors would also like to thank David Rodgers and Marcy Rood of the U.S. Department of Energy's Clean Cities Program and Rajeana Gable of the Gas Research Institute (GRI) for their support of the May 2000 training session and technical guidance throughout the project.

Table of Contents

Figures

Tables

Overview

The transportation sector accounts for a large and growing share of global greenhouse gas (GHG) emissions. Worldwide, motor vehicles emit well over 900 million metric tons of CO_2 each year, accounting for more than 15 percent of global fossil fuel CO_2 releases.[1] In the industrialized world alone, 20-25 percent of GHG emissions come from the transportation sector. The share of transport-related emissions is growing rapidly due to the continued increase in transportation activity.[2] In 1950, there were only 70 million cars, trucks, and buses on the world's roads. By 1994, there were about nine times that number, or 630 million vehicles. Since the early 1970s, the global fleet has been growing at a rate of 16 million vehicles per year. This expansion has been accompanied by a similar growth in fuel consumption.[3] If this kind of linear growth continues, by the year 2025 there will be well over one billion vehicles on the world's roads.[4]

The purpose of this publication, "Greenhouse Gas Emission Reductions and Natural Gas Vehicles: A Resource Guide for Project Development" is to provide national and international project developers and other entities with a guide on how to estimate and document the GHG emission reduction benefits and/or penalties of natural gas vehicle (NGV) projects. This primer also provides a resource for the creation of GHG emission reduction projects for the Activities Implemented Jointly (AIJ) Pilot Phase and in anticipation of other potential market-based project mechanisms. Although it will be necessary for project developers to evaluate the emission benefits of each NGV project on a case-by-case basis, this primer provides guidance for determining which data and information to include during the process of developing the project proposal.

Unlike stationary energy combustion, transportation-related emissions come from dispersed sources. Only a few point-source emitters, such as oil/natural gas wells, refineries, or compressor stations, contribute to emissions from the transportation sector. The majority of transport-related emissions come from the millions of vehicles traveling the world's roads. To increase regulatory effectiveness, policies to control emissions from the transportation sector often utilize indirect means to reduce emissions, such as requiring specific technology improvements or an increase in fuel efficiency. Site-specific project activities can also be undertaken to help decrease emissions from the transportation sector, although the use of such measures is less common. As emissions from transportation activities continue to rise, it will be necessary to promote both types of abatement activities to reverse the current emissions path. In the following report, we will focus on site- and project-specific transportation activities.

To date, only a few projects deploying NGV technologies have been developed and implemented specifically with the purpose of reducing GHG emissions and participating in international GHG reduction initiatives. Therefore, experience with quantifying, evaluating, and verifying GHG emission reductions from natural gas vehicle projects is almost non-existent. This is a problem as there are many issues unique to the transportation sector, which should be resolved before adequate guidelines can be

---

[1] World Resources Institute, *Proceed With Caution: Growth in the Global Motor Vehicle Fleet,* http://www.wri.org/trends/autos.html.

[2] "Good Practice Greenhouse Abatement Policies: Transport Sector," OECD and IEA Information Papers prepared for the Annex I Expert Group on the UNFCCC. OECD and IEA, Paris, November 2000. Emissions exclude land-use change and forestry, and bunker fuels. Annex I countries are those countries that have undertaken binding emission reduction targets under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC).

[3] American Automobile Manufacturers Association (AAMA), *World Motor Vehicle Data 1993* (Washington, D.C., 1993), p. 23, and American Automobile Manufacturers Association (AAMA), *Motor Vehicle Facts and Figures 1996* (Washington, D.C., 1996).

[4] World Resources Institute, *Proceed With Caution: Growth in the Global Motor Vehicle Fleet,* http://www.wri.org/trends/autos.html.

developed for evaluating transportation-related projects. Issues that will require further analysis and guidance include:

1. Methods for cost-effectively and accurately estimating emission reductions for a dispersed number of sources;
2. Procedures for determining project boundaries and relevant GHG emission sources;
3. Options for minimizing transaction costs of validating, monitoring, verifying, and certifying potential emission reductions; and
4. Guidance on using a full fuel-cycle or tailpipe emission analysis to estimate project emissions.

The main purpose of this manual is to provide information on quantifying and documenting GHG emission reductions from NGV projects. Moreover, to provide potential project developers with an overview of project opportunities in the NGV sector, the manual also includes information on NGV technology cost and availability and discusses the future of the alternative fuel vehicle (AFV) industry as a whole.

Chapter 1 of this report provides an outline of NGV technology availability, including information on safety, cost, vehicle types, and refueling infrastructure. The purpose of this chapter is to provide an understanding of the availability of NGV technologies in the short-term and to describe worldwide deployment.

In Chapter 2, the report describes domestic and international regulatory frameworks for NGVs. It provides information on existing and pending regulatory activities under which an NGV project developer could receive credits for initiating an NGV GHG emission reduction project. International programs and activities discussed in Chapter 2 include the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, the AIJ Pilot Phase, the Clean Development Mechanism (CDM), and Joint Implementation (JI). Domestic programs include a discussion of the Clean Air Act (CAA) and the Clean Air Act Amendments of 1990 (CAAA90), the Energy Policy Act of 1992, the U.S. Department of Energy's (DOE) Voluntary Reporting of Greenhouse Gases Program, the National Energy Technology Laboratory (NETL) Strategic Center for Natural Gas (SCNG), the DOE Clean Cities Program, and U.S. Department of Transportation (DOT) Programs.

Chapter 3 examines the GHG emissions associated with NGV use and reviews recent literature and models for estimating NGV-associated GHG emissions. The chapter also summarizes current projects deploying transportation technologies and analyzes the outcome of quantifying tailpipe emissions instead of full fuel cycle emissions from NGV use. Chapter 3 concludes with a discussion of the barriers to the implementation of transportation-related GHG mitigation projects and provides suggestions for measures to overcome such barriers.

A case study describing the steps necessary to quantify and document GHG emission reductions from an NGV project applying criteria under the UNFCCC is included in Chapter 4. This chapter provides a step-by-step description of developing emission baselines and estimating net GHG emission benefits of a hypothetical project replacing gasoline-fueled taxis with compressed natural gas-fueled taxis. The case study includes an analysis of both tailpipe and full fuel cycle emissions of the project.

NGVs are a subset of a larger group of transportation technologies also known as alternative fueled vehicles (AFVs). This group includes vehicles powered by alternative sources, such as fuel cells, electric batteries, or biomass. Chapter 5 examines the future prospects of these AFVs. The commercial deployment of NGVs continues to increase worldwide, but as NGV use grows, automobile manufacturers and governments are also researching new AFV technologies and ways to improve existing technologies. Other advanced technologies, with potential for reducing GHG emissions, include electric vehicles, hybrid electric vehicles, hydrogen fuel cells, and gas-to-liquid technologies, also known as "clean diesel." Though numerous applications of AFVs can be examined, only the above listed technologies are discussed in this Chapter, due to their medium- to long-term potential as substitutes for NGVs.

1. Natural Gas Vehicle Technology Options

1.1 Introduction

The objective of this chapter is to familiarize the reader with the different NGV technology options currently available and provide an overview of the NGV deployment status worldwide.[5] The chapter provides detailed information on safety, cost, and infrastructure availability of NGVs. This background information is critical for project developers and other entities evaluating the additionality and baselines of a potential GHG reduction project. The procedures for baseline development will be discussed in more detail in Chapters 3 and 4 of this report.

1.2 Natural Gas as a Transportation Fuel

Natural gas is a mixture of gaseous hydrocarbons. The primary component of natural gas is methane, but smaller amounts of ethane, propane, butane, carbon dioxide, and other trace gases are also included in the fuel. The specific mixture of natural gas delivered by pipeline varies by region. It is produced from gas wells or in conjunction with crude oil production; it can also be produced as a byproduct of landfill and coal mining operations.

Table 1. Characteristics of Natural Gas for Transportation Fuels

	Compressed Natural Gas (CNG)	**Liquefied Natural Gas (LNG)**
Chemical Structure	CH_4	CH_4
Primary Components	Methane	Methane that is cooled cryogenically
Main Fuel Source	Underground reserves	Underground reserves
Energy Content per Gallon	29,000 Btu	73,500 Btu
Energy Ratio Compared to Gasoline	3.94 to 1 or 25% at 3000 psi	1.55 to 1 or 66%
Liquid or Gas	Gas	Liquid

Source: Alternative Fuels Data Center (AFDC), http://www.afdc.doe.gov/questions.html.

During vehicle operations, natural gas can be stored as either a gas (compressed natural gas) or a liquid (liquefied natural gas). Table 1 describes in more detail the characteristics of the natural gas fuels used for transportation. CNG is natural gas that has been compressed under high pressure, typically between 2000 and 3600 pounds per square inch (PSI). LNG is natural gas that has been condensed to a liquid by reducing its temperature to -260 degrees Fahrenheit at atmospheric pressure. In order to maintain it as a liquid, LNG must remain below -117 degrees Fahrenheit. LNG is half the weight of water and is odor-less, non-corrosive and non-toxic. LNG differs from CNG in the following areas:

[5] This chapter focuses on NGV technologies and deployment in the U.S. market. NGVs are also used in other countries such as Argentina, Brazil, Canada, Egypt, Italy and Russia. Please see Section 1.5 of this chapter for more information on vehicle use in these countries.

- The higher energy density of LNG requires less storage space and shorter refueling time;
- The occurrence of liquid slugs in LNG can reduce gasification efficiency;
- The liquid composition of LNG allows for transportation via trucks, railcars, barges, or ships; and
- The ability to better control the fuel composition (i.e. CH_4 content) facilitates increased engine performance and fuel economy.

In the U.S., CNG is the most commonly used form of natural gas although heavy-duty vehicle fuel markets are developing rapidly for liquefied natural gas (LNG). For the remainder of this report, information that applies to both CNG and LNG will be presented as information about NGVs; information that is specific to either CNG or LNG will be noted as such.

The performance of today's NGVs, whether CNG or LNG, is comparable to gasoline-powered vehicles. The only major difference between a gasoline vehicle and an NGV is the fuel system. Natural gas is compressed to between 3,000 and 3,600 pounds per square inch (psi) and is stored on board the vehicle in cylinders installed in the rear, undercarriage, or on the roof. When natural gas is required in the engine, it leaves the cylinders, passes through a master manual shut-off valve and a high-pressure fuel regulator located in the engine compartment. The natural gas is injected at atmospheric pressure through a specially designed natural gas mixer where it is properly mixed with air. The natural gas then flows into the engine's combustion chamber and is ignited to create the power required to drive the vehicle. Special solenoid-operated valves prevent the gas from entering the engine when it is shut off.

1.3 Natural Gas Vehicle Types

Natural gas vehicles can be dedicated or dual-fuel vehicles and are available as light, medium, and/or heavy-duty vehicles. Dedicated vehicles are designed to run on only one type of fuel, while dual-fuel vehicles run on natural gas and either gasoline or diesel. The advantage of dual-fueled vehicles is that the range of the vehicle can be extended, and the vehicle can continue to be driven if no natural gas refueling station is available. However, with the proper application, the local pollutant and GHG emission benefits of a dedicated NGV are greater than a dual-fueled NGV.[6]

1.3.1 Light-Duty Vehicles

Light-duty vehicles are classified as having a gross vehicle weight of less than 8,500 pounds (3,850 kg). Typically, passenger cars, small vans, and small trucks are considered to be light-duty vehicles. For model year 1999, a typical light-duty CNG vehicle has a driving range of 120-180 miles. (Due to differences in LNG vehicle types, it is not possible to estimate a range.) Light-duty NGVs are typically best suited for fleet use, because this application allows them to be returned to a central location for refueling. Fleet vehicles currently make up the majority of light-duty NGVs on the road today in countries including Argentina, Canada and the U.S.

Table 2 demonstrates that all the major U.S. automobile manufacturers (Ford, General Motors, and DaimlerChrysler) have built prototype light-duty NGVs. For model years 2000-2001, there are five

[6] With respect to local air pollutants (carbon monoxide, oxides of nitrogen and particulate matter) exhaust emissions from NGVs are much lower than gasoline-powered vehicles: NGV emissions of carbon monoxide are approximately 70 percent lower; non-methane organic gas emissions are 89 percent lower; and oxides of nitrogen emissions are 87 percent lower. In addition to these reductions, NGVs also emit significantly lower amounts of GHGs and toxins. Dedicated NGVs produce little or no evaporative emissions during fueling and use, while evaporative and fueling emissions account for at least 50 percent of a gasoline vehicle's total hydrocarbon emissions.

manufacturers offering NGVs to U.S. consumers (the three U.S. automakers plus the U.S. operations of Honda and Toyota). All of the NGVs offered by these manufacturers are fueled by CNG.

Table 2. Light-Duty NGV Manufacturers

Manufacturer	Body Type	Vehicle Type	Fuel Type
American Honda Motor Co. Inc.	Sedan	Dedicated	CNG
DaimlerChrysler	Van, Wagon	Dedicated	CNG
Ford Motor Co.	Sedan, Pickup, Van, Wagon	Dedicated, Dual-fuel	CNG
General Motors Corp.	Sedan, Pickup	Dual-fuel	CNG
Toyota Motor Sales, U.S.A., Inc.	Sedan	Dedicated	CNG

Source: *1999-2000 Natural Gas Vehicle Purchasing Guide*, Natural Gas Vehicle Coalition (NGVC), http://www.ngvc.org.

1.3.2 Medium-Duty and Heavy-Duty Vehicles

Medium-duty vehicles are classified as having a gross vehicle weight of between 8,500 pounds and 14,000 pounds (3,850 and 6,350 kg). Medium-duty vehicles typically include trucks, vans, cargo vehicles, shuttle buses, and street sweepers. Heavy-duty vehicles are classified as having a gross vehicle weight of greater than 14,000 pounds (6,350 kg). Heavy-duty vehicles include large trucks, transit buses, and school buses. Trucks are suitable for both CNG and LNG use because they have high fuel consumption rates, which reduce the payback time. Some of the country's delivery fleets currently using NGVs include the United Parcel Service and the U.S. Postal Service.

There are a number of operational issues for medium- and heavy-duty NGVs that differ from conventional diesel-powered vehicles. The first issue is that of vehicle range. Due to the lower density of natural gas compared to gasoline, NGVs must have extra fuel storage capacity in order to have the same range as gasoline- or diesel-powered vehicles. This increase in fuel storage area can lead to a decrease in cargo storage area. Second, there are two types of re-fueling options available for NGVs: slow-fill and fast-fill. In the case of slow-fill refueling, longer refueling times must be taken into consideration. Finally, maintenance issues should be considered. Due to the cleaner burning properties of natural gas, there is a reduction in vehicle maintenance. Specifically, natural gas engines run much cleaner than gasoline or diesel engines, as there is no accumulation of fuel oil deposits. Even the used engine oil of a NGV engine retains its golden color and is cleaner to handle for disposal or re-refining. However, braking systems may require additional maintenance and storage cylinders should be pressure tested and visually inspected for surface damage every five years.

Most manufacturers of diesel engines now offer comparable natural gas versions of these engines. Table 3 provides a list of manufacturers offering medium- and heavy-duty NGVs.

Table 3. Medium- and Heavy-Duty NGV Manufacturers

Manufacturer	Vehicle Types	Fuel Types
Blue Bird Corporation	Bus	CNG, LNG
Champion Bus, Inc.	Bus	CNG
ElDorado National	Bus	CNG, LNG
Freightliner	Bus, Truck	CNG, LNG
Mack Trucks, Inc.	Truck, Refuse Hauler	CNG, LNG
Neoplan USA Corp.	Bus	CNG, LNG
New Flyer of America	Bus	CNG
North American Bus Industries	Bus	CNG
Nova Bus	Bus	CNG, LNG
OmniTrans Distributing	Bus, Truck	CNG, LNG
Orion Bus Industries	Bus	CNG
Peterbilt Motors Co.	Refuse Truck	CNG, LNG
Spartan Motors Chassis, Inc.	Bus	CNG, LNG
Thomas Built Buses	Bus	CNG
Western Star Trucks	Truck	CNG, LNG

Source: 1999-2000 Natural Gas Vehicle Purchasing Guide, Natural Gas Vehicle Coalition (NGVC), http://www.ngvc.org.

1.4 Natural Gas Vehicle, Fuel, and Infrastructure Cost

The cost of NGVs will differ depending on whether the vehicle is a dedicated natural gas vehicle from an original equipment manufacturer (OEM) or it is converted from a gasoline-powered vehicle. Original equipment NGVs are more expensive than their gasoline-or diesel-powered counterparts. DaimlerChrysler, for example, charges about $4,000 more for a light-duty natural gas vehicle than a gasoline-only model.[7] General Motors Corporation (GMC) charges approximately $3,700 more than a gasoline vehicle, but these figures may vary depending on vehicle and number of fuel cylinders. With more vehicles coming on the market, this cost-differential is expected to decrease. The cost-disadvantage of converting a gasoline-powered vehicle to a NGV is slightly less than purchasing a dedicated vehicle. The price of converting a vehicle to natural gas-use currently ranges between $2,500 - $4,000.[8] This large price range is based on a variety of factors, including vehicle type, number of fuel tanks, and labor and installation costs.

Although, the cost of NGV technologies is higher than conventional vehicle technologies, the lower natural gas price can offset the economic disadvantage caused by the high equipment cost. Table 4 provides a cost comparison of gasoline and CNG. The table illustrates that the price of gasoline is less stable than natural gas prices and that gasoline prices continue to rise at a greater rate than the price of CNG. Many natural gas utilities and other sources note the lower cost of natural gas as fuel. In 1999, in the Puget Sound region, natural gas cost $0.80 per gallon gasoline equivalent (gge) (when purchased through Puget Sound Energy).[9] It can be considerably less if an individual fleet operator owns his/her

[7] California Energy Commission, "NGV–Fuel and Vehicle History and Characteristics," http://www.energy.ca.gov.
[8] Alternative Fuels Data Center, http://www.afdc.nrel.gov/afv/conversion.html.

[9] Pacific Northwest Pollution Prevention Center (PPRC), "Alternative Fuels for Fleet Vehicles," http://www.pprc.org.

own station: $0.45 per gge. It can be even cheaper if the fleet manager decides to purchase the natural gas directly from the producers. Although prices are dependent upon the local natural gas utility, these numbers are good estimates for the cost of natural gas fleets.

Table 4. Cost Comparison between Gasoline and CNG (1990-2000)

Year	Gasoline ($ / gallon)	Annual Gasoline Price Change (%)	CNG ($/1000 Cu Ft.)	Annual CNG Price Change (%)
1990	1.22		3.39	
1991	1.20	-1.6	3.96	16.8
1992	1.19	-.80	4.05	2.3
1993	1.17	-1.7	4.27	5.4
1994	1.17	0.0	4.11	-3.7
1995	1.21	3.4	3.98	-3.2
1996	1.29	6.6	4.34	9.0
1997	1.29	0.0	4.44	2.3
1998	1.12	-13.2	4.59	3.4
1999	1.22	8.9	4.34	-5.4
8/2000	1.56	27.9	NA	NA

Sources: Energy Information Administration, *Monthly Energy Review,* Table 9.4, Washington, DC, 2000. Energy Information Administration, *Natural Gas Annual, 1999*, Table 95, Washington, DC, 2000.

Besides information on vehicle equipment and fuel supplies, project developers should also consider the cost of installing refueling infrastructure. A 1997 estimate for installing fast-fill compressor facilities for a small private or public fleet of about ten vehicles in California ranged between $180,000 to $250,000.[10]

1.5 NGV Vehicle Maintenance, Infrastructure and Safety

The body and structure of NGVs are similar to conventionally fueled vehicles, which means that maintenance requirements essentially are the same for all non-engine vehicle components. However, there are other maintenance issues that are unique to NGVs. CNG cylinders and LNG tanks should be inspected periodically, and the former should be re-certified to maintain standards. Re-certification is a process of examining the cylinders for manufacturing defects, cracks, or other signs of wear and tear. Gasoline fuel systems on dual-fuel vehicles should be run at least once per week to prevent drying and cracking of the gasoline system. Due to the clean burning properties of natural gas, engine oil will not appear dirty. However, engine oil breaks down over time and should be changed at manufacturer-recommended intervals. Vehicle manufacturer recommendations also should be followed for spark plug changes. Also, in the case of LNG vehicles, the fuel is cooled cryogenically to -260°F. At this temperature, bodily contact with the liquid fuel, cold metals, or cold gas can cause cryogenic burns (frostbite). Methane gas detectors must be installed to detect leaks, because odorants cannot be added to LNG.

[10] Ibid.

1.5.1 Re-Fueling Station Requirements

Unlike gasoline or diesel, which must be processed from crude oil in large, complex refineries, natural gas requires very little processing to make it suitable for use as a transportation fuel. After water vapor, sulfur, and heavy hydrocarbons are removed, natural gas can be transported via pipeline directly to a NGV refueling station where it is compressed for use. Alternatively, it can be liquefied and stored at the refueling station or transported in liquid form by truck to the station. NGV refueling stations can either be classified as slow-fill or fast-fill. Fast-fill systems can refuel a vehicle in 3 to 5 minutes, but are more costly to build and operate. Slow-fill systems are less costly, but take 6 to 12 hours to refuel a vehicle.

Slow-fill stations attach the vehicle directly to a compressor and have little or no storage capacity. These stations are used primarily for fleet vehicles that can remain idle in a single location over a longer period of time. Publicly available NGV stations are typically fast-fill stations with high-pressure storage for faster refueling.

1.5.2 Basic Refueling Station

The basic NGV refueling station is made up of the following typical components: compressor, controls, ground storage, and dispensing and metering. Gas is transported through pipelines in a non-compressed state. However, prior to refueling, the gas must be compressed to approximately 3,600 PSI. In the case of LNG, the gas is liquefied, and must be kept in a liquid state until the time of refueling. There are a number of controls that monitor the flow of natural gas. These include the controls to and from the compressor, the gas recovery system, and the dispenser. Underground tanks, made of a double-wall construction, are used to store LNG.[11] In the case of slow-filled NGVs, there is no need for on-site storage as the natural gas can be routed directly from the pipeline to the compressor station.

1.5.3 Refueling Safety

The overall safety record of natural gas, including its use as a vehicle fuel, is superior to that of conventional vehicle fuels. Although natural gas becomes flammable in air if it is stored in concentrations of 5 to 15 percent, the gas has certain characteristics that make it inherently safe. Natural gas is a vapor rather than a liquid. Unlike liquid fuels, which will pool on the ground when leaked or spilled, natural gas will dissipate into the atmosphere because it is lighter than air. The ignition temperature of natural gas is also much higher than gasoline; 1,200 degrees Fahrenheit compared to 600 degrees Fahrenheit. To aid in the detection of leaks, natural gas has odorants added to it. During the liquefaction process, however, these odorants are removed, making detection of LNG leaks much more difficult.

To improve fuel safety, natural gas storage tanks are made of steel, aluminum, and/or composite materials and are much stronger than gasoline tanks.

Despite the overall safety of natural gas compared to other liquid fuels, there are a number of refueling safety concerns to be considered for both CNG an LNG. Users of CNG are particularly concerned with the increased fire hazard and the problems associated with failures in the pressure relief system. Natural Gas is flammable in air, in concentrations of 5 to 15 percent. In an enclosed area, natural gas will rise to the ceiling and in the absence of proper ventilation systems; the build-up could result in a fire or ignition risk. The built-up natural gas could also cause asphyxiation, if enough oxygen is displaced. In addition,

[11] The inside tank is surrounded first by a layer of insulation and then by an outside tank.

if high-pressure refueling systems fail, injury could result from release of small particles, fire, or excessive noise.

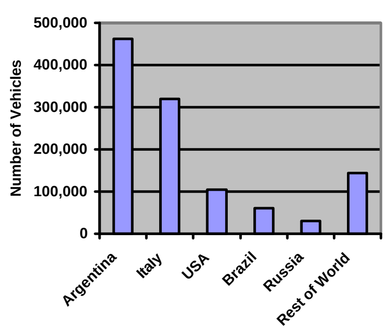
LNG has a higher potential for causing fire in indoor fueling facilities. If LNG is leaked or spilled, it will revert to its gaseous form and rise to the ceiling. Without proper ventilation, the resulting build-up of natural gas increases the risk of ignition. Moreover, due to the temperature of LNG, exposure to human skin will result in a cold burn. Prolonged exposure will result in permanent damage to exposed skin areas. Finally, even though LNG is non-toxic, LNG vapor could displace air and pose an asphyxiation hazard. Due to the vapor's temperature, prolonged exposure to LNG vapor will result in lung tissue damage.

1.6 Current Trends in Deployment of NGVs

As of August 2000, there were approximately 1.1 million converted NGVs in operation throughout the world.[12] In the United States alone, there were 103,673 converted and original equipment NGVs, a 1.7 percent increase from 1999. Of the U.S. total, 101,991 vehicles ran on CNG and 1,682 vehicles ran on LNG, an increase from 1999 of 1.6 percent and 18.3 percent, respectively. Since 1992, the average annual growth rate in the U.S. for CNG and LNG vehicles were 20.3 percent and 44.2 percent, respectively.[13] Most NGVs in the United States and elsewhere are converted vehicles; however, the number of dedicated vehicles offered from OEMs is increasing.[14]

As illustrated in Figure 1, Argentina and Italy lead the world with 462,186 and 320,000 converted NGVs, making up more than half the world total.[15] The United States, Brazil, and Russia follow these two countries, with approximately 104,000, 60,000, and 30,000 vehicles, respectively.

Figure 1. Number of Converted NGVs Worldwide



Source: International Association for Natural Gas Vehicles, "International Natural Gas Vehicle Statistics 2000 Online," http://www.iangv.org/html/ngv/stats.html.

---

[12] International Association for Natural Gas Vehicles, "International Natural Gas Vehicle Statistics 2000 Online," http://www.iangv.org/html/ngv/stats.html

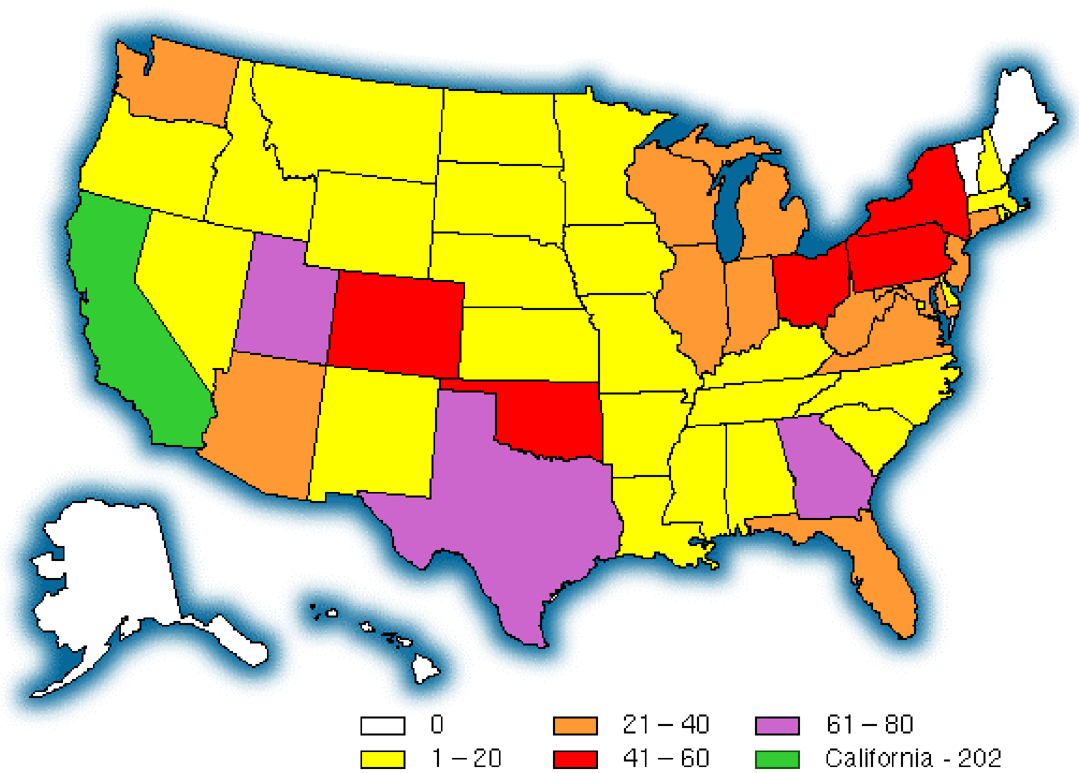
[13] Energy Information Administration, *Alternatives to Traditional Transportation Fuels 1998*. Table 1, http://www.eia.doe.gov/cneaf/solar.renewables/alt_trans_fuel98/table1.html

[14] The DOE Clean Cities Program defines a converted vehicle as a vehicle that was originally designed to operate on gasoline but has been altered to run on alternative fuel. The two most common fuel-switching alternatives include CNG and liquefied petroleum gas (LPG), also commonly referred to as propane.

[15] Similar statistics on OEM NGVs are not readily available.

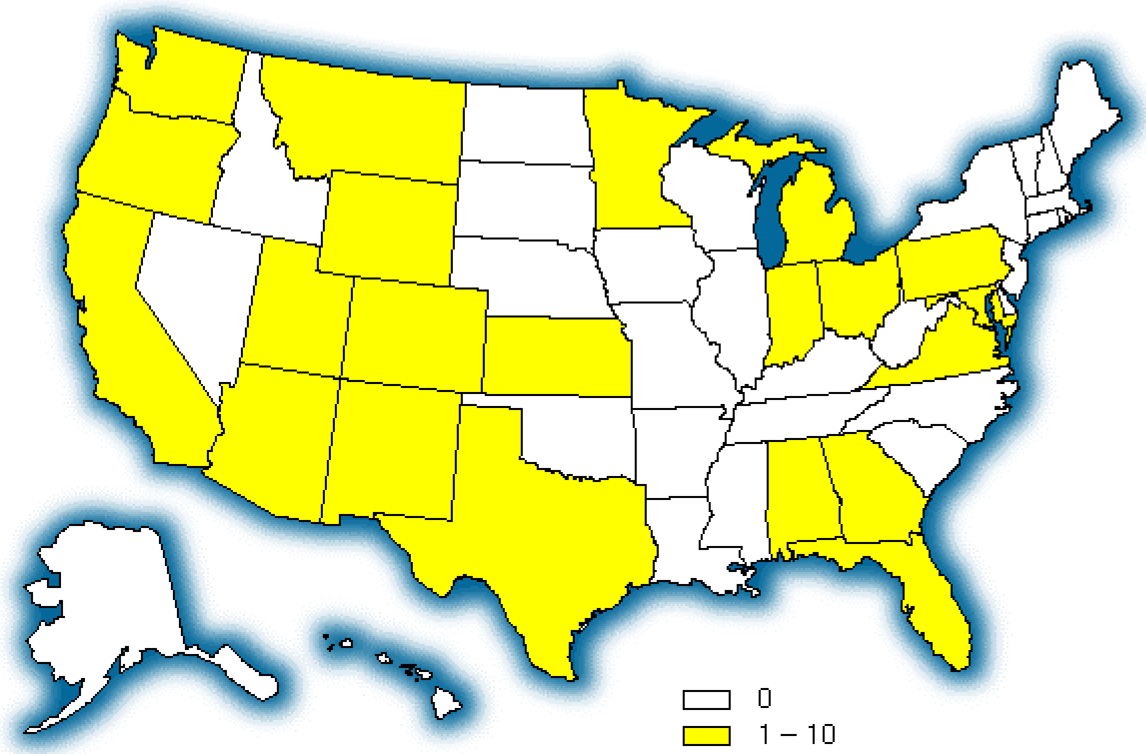
Despite trailing other countries in numbers of NGVs, the United States has the highest concentration of NGV refueling stations. The total number of NGV refueling stations worldwide is 3,885, with approximately 32 percent (1,263) of these located in the United States. Argentina (830), Italy (320), Canada (222), and Venezuela (151) follow the United States. As for individual States, California leads the nation with more than 200 refueling stations followed by Texas (77), Georgia (69), Utah (63), and New York (59). Only four states, Alaska, Hawaii, Maine, and Vermont do not have any NGV refueling sites (see Figures 2 and 3). However, the number of U.S.-based NGV refueling stations still pales in comparison to the number of gasoline stations. There are approximately 180,000 gasoline stations throughout the United States.

Figure 2. CNG Refueling Site Locations in the U.S.



Source: Alternative Fuels Data Center: http://www.afdc.nrel.gov/altfuel/cng.html.

Figure 3. LNG Refueling Site Locations in the U.S.



Source: Alternative Fuels Data Center: http://www.afdc.nrel.gov/altfuel/lng.html.

2. Domestic and International Regulatory Framework for NGVs

2.1 Introduction

Numerous regulatory policies have been implemented in the U.S. and abroad to facilitate the development of NGV projects. Many of these policies have been introduced specifically with the purpose of reducing GHGs. NGV technology development and implementation are also being promoted at both domestic and international levels, opening considerable opportunities for the initiation of new NGV projects.

International agreements on the control of GHG emissions are not legally binding on domestic activities at this time. The international framework is considered in this report to provide insight into the direction domestic legislation may soon take. This chapter begins with a description of international legislative developments that could have an influence on the number of climate change mitigation projects using NGV technologies. The chapter also provides an overview of U.S. regulations that affect the deployment of NGVs, including the primary Federal Regulations.[16]

2.2 International Framework for Promoting GHG Emission Reduction Projects

International efforts to limit the release of GHGs gained momentum at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in June 1992. This conference proved to be a turning point in the effort to reduce GHGs[17] as well as the first public commitment on the part of many nations to take specific actions to limit their emissions. The Rio Conference established the United Nations Framework Convention on Climate Change (UNFCCC), under which industrialized countries voluntarily agreed to reduce their GHG emissions to 1990 levels by the year 2000.[18] The U.S. Government ratified the UNFCCC on October 15, 1992 and is therefore considered a "Party" to the Convention. The Parties to the Convention meet every year at the ministerial level (Conference of the Parties (COP)) and more often at the technical level to oversee and guide the implementation of the UNFCCC. From these annual COP meetings, and other meetings held by the subsidiary bodies to the UNFCCC, come most of the guiding international framework under which nations endeavor to limit GHG emissions.

Several initiatives have been proposed under the UNFCCC to promote and credit project-based GHG reduction activities. Figure 4 provides an overview of the mechanisms that are particularly relevant for project developers interested in creating NGV projects. In 1995, the Parties to the Convention established the Activities Implemented Jointly (AIJ) Pilot Phase, under which a framework for developing and implementing emission reduction projects jointly between two or more countries was developed. This concept is generally known as joint implementation (JI). Moreover, the Kyoto Protocol to the UNFCCC was introduced in 1997.[19] The Protocol must be ratified by the Parties to the Convention before

---

[16] "U.S. Federal Incentives and Regulations Affecting the Use of NGVs." Put together by DOE's Clean Cities Program, this website details the current Federal, State, local and private incentives and Federal, State and local laws that affect NGVs. A contact name and phone number is included for each incentive. http://www.fleets.doe.gov/fleet_tool.cgi?$$,benefits.

[17] The most common anthropogenic (human-caused) greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6). There are other gases that trap heat in the earth's atmosphere, however the six gases (and classes of gases) mentioned above are those currently covered by international treaty.

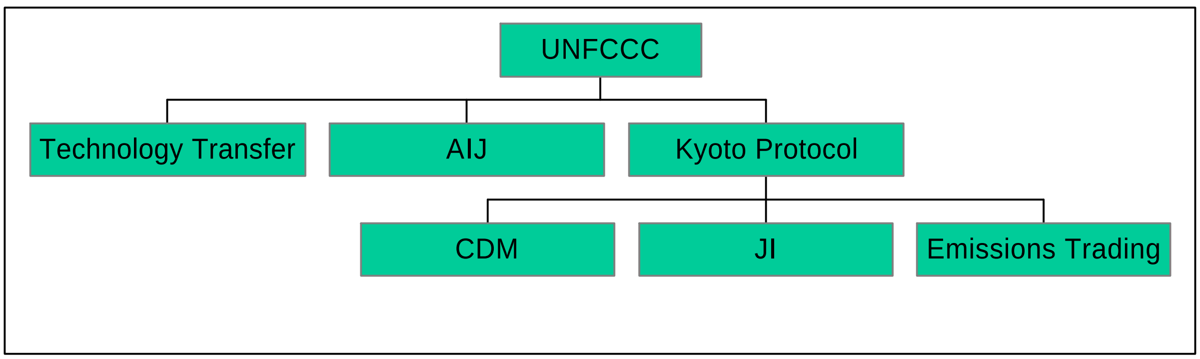
[18] United Nations Framework Convention on Climate Change (UNFCCC), http://www.unfccc.int/resource/conv/conv_002.html.

[19] The Kyoto Protocol to the United Nations Framework Convention on Climate Change, http://www.unfccc.de/resource/docs/convkp/kpeng.html.

it can enter into force.[20] The Protocol language establishes legally binding emission reduction targets for industrialized countries. The rules of the Protocol are still under development and it is unclear whether Parties will be able to come to an agreement on an acceptable framework for ratification and implementation of the Protocol. The U.S. Government signed the Kyoto Protocol on November 12, 1998 but the White House Administration has expressed its opposition against the Protocol in its current form because it fails to adequately include developing countries.

The Kyoto Protocol allows for two project-based mechanisms that would encourage the development of NGV-related projects in exchange for certified emission reduction units: the Clean Development Mechanism (CDM) – projects between actors in an industrialized and a developing country; and Joint Implementation (JI) – projects between actors in industrialized countries. In the following subsections, each of the NGV project development and technology transfer mechanisms proposed under the UNFCCC will be described in further detail.

Figure 4. NGV Project Development and Technology Transfer Mechanisms under the UNFCCC



2.2.1 NGV-Related GHG Mitigation Projects under the United Nations Framework Convention on Climate Change

The text of the United Nations Framework Convention on Climate Change (UNFCCC) was officially adopted at the United Nations Headquarters, New York City, on May 9, 1992. The UNFCCC has subsequently become the primary international agreement for preventing human-induced climate change, committing industrialized (Annex I) countries to stabilize atmospheric concentrations of GHGs and providing an institutional forum to achieve this objective. In addition to taking on voluntary reduction targets, the Parties to the Convention agreed to develop national programs to slow the release of harmful emissions and to take climate change into account in such matters as agriculture, energy, natural resources, and activities involving coastal areas. The Parties also agreed to share technology internationally and to cooperate in other ways to reduce GHG emissions, especially in the energy, transport, industry, agriculture, forestry, and waste management sectors. Together, these sectors produce nearly all of the GHG emissions that can be attributed to human activities. However, the Convention does not establish legally binding emission reduction requirements for the signatories.

As a result of the potential GHG emission benefits associated with switching from gasoline to natural gas fueled vehicles, the promotion of NGV projects would support many of the major goals set forth in the

[20] The Protocol will enter into force on the ninetieth day after the date on which no less than 55 Parties to the Convention, incorporating Annex I Parties which account for at least 55% of the total carbon dioxide emissions for 1990 from that group, have deposited their instruments of ratification, acceptance, approval or accession.

convention. For instance, the development of individual NGV projects and the adoption of policies to promote the use of NGVs would greatly enhance national efforts to limit emissions of GHGs. Industrialized countries could also fulfill their commitment to share technology and cooperate with other nations by facilitating the transfer of NGV technologies to developing countries, for example through participation in AIJ projects.

Activities Implemented Jointly (AIJ) Pilot Phase

The UNFCCC introduced the concept of joint implementation (JI), which refers to arrangements through which an entity in one country partially meets its domestic commitment to reduce GHG levels by financing and supporting the development of a project in another country. To test the concept of JI, the Activities Implemented Jointly (AIJ) Pilot Phase was established at the first Conference of the Parties to the UNFCCC (COP-1), held in Berlin in 1995. Projects initiated during this phase were called "activities implemented jointly" to distinguish them from the full-fledged JI projects the Convention may allow in the future. The goal of the AIJ Pilot Phase was to provide developing nations with advanced technologies and financial investment while allowing industrialized nations to fulfill part of their reduction commitment at the lowest cost.   Because of the temporary pilot status of this program, it was decided that project developers cannot receive credit or other monetary incentives for projects developed and approved as part of this initiative.

The Parties adopted three basic criteria for the pilot phase of AIJ:

- The activity must be officially approved as an AIJ project by both countries involved;
- The activity must result in real, measurable and long-term reductions in net GHG emissions that would not have occurred in the absence of such an activity; and
- The activity should be financed outside current Official Development Assistance (ODA) funds.

Although the AIJ Pilot Phase provides a unique opportunity for the development and recognition of NGV-related GHG emission reduction projects, few such projects have actually been implemented. Of the 144 AIJ projects currently approved by the designated national authorities for AIJ, there is only one transportation project.[21] The two most common types of AIJ projects are land use (including forest conservation, forestry, and sustainable forest management) and energy (primarily stationary combustion and fuel switching projects).

The only transportation project currently approved under the AIJ Pilot Phase is a project developed to test and advance NGV technologies in Hungary. This project, which is called the RABA/Ikarus Compressed Natural Gas Engine Project, is being carried out between project developers in the Netherlands and Hungary. The project is intended to transfer technology and hardware to Hungary (specifically to two vehicle manufacturers, RABA and Ikarus) to assist manufacturers in building and delivering new CNG vehicles to the Hungarian market. The goal of the project is to replace old public transport diesel buses with new CNG buses.   The project is also expected to build market potential for the Dutch companies involved, as well as to strengthen the economic position of the Hungarian companies receiving the technology transfer. The initial cost estimate of GHG emission reductions resulting from the project ranges between \$100 and \$250 per ton of CO_2 equivalent reduced.   Approximately 39 percent of the initial funding for this project were to come from the Dutch Government, another 39 percent from the Hungarian Government, and the remaining 22 percent from other Hungarian sources. At the time of AIJ

[21] See UNFCCC AIJ (http://www.unfccc.de/program/aij/aijproj.html) for more information.

approval, the project was expected to achieve 7,400 tons of CO_2 reductions per year and to continue to achieve reductions for over 20 years.[22]

At least one other transportation-related AIJ project is currently being considered for development. Also a natural gas vehicle project, this AIJ project would be conducted between project developers in the United States and Chile and would switch 100 buses or taxis from diesel or gasoline to natural gas. The limited number of transportation-related AIJ projects is by no means a reflection of the transportation sector's share of total GHG emissions (which is significant). Recognizing the need to exploit more fully the opportunities offered by low-emitting transportation technologies, the countries promoting participation in the AIJ Pilot Phase are eager to help facilitate development of projects in the transportation sector. In this connection, NGV projects are often cited as relevant mitigation activities due to the many local energy and environmental side benefits of such projects.

Since the initiation of the AIJ Pilot Phase, a number of countries, including Australia, Canada, Costa Rica, Germany, Japan, Poland, Sweden, Switzerland, the Netherlands, and the U.S., have set up national offices to facilitate and evaluate JI projects. In addition, several other countries have identified a designated focal point within their governments to oversee the development and approval of JI projects.[23] In the following subsection, the U.S. program for evaluating projects, the U.S. Initiative on Joint Implementation (USIJI), will be described in more detail. USIJI is one of the largest JI programs established during the AIJ Pilot Phase and has established some of the most stringent application criteria for project development.

U.S. Initiative on Joint Implementation (USIJI)

Recognizing the enormous potential for cost-effective GHG emission reductions in other countries, the Clinton Administration created the U.S. Initiative on Joint Implementation (USIJI) as part of the U.S. Climate Change Action Plan (CCAP).[24] USIJI was designated as the official U.S. Government institution accepting jointly implemented GHG emission reduction projects as part of the AIJ Pilot Phase. The USIJI is overseen by an Interagency Working Group (IWG) that has the primary responsibility for policy development and criteria used for project acceptance. A key goal of the USIJI program is to influence the technological choices associated with the already substantial private capital flows to developing countries. The goal of the current pilot phase is to gain experience and knowledge that can be used as a basis for developing a fully-fledged market-based program in the future. However, at the time of writing this report, the status of USIJI has been put on hold pending a U.S. government review of its overall climate change strategies.

Benefits of USIJI activities accrue to the U.S., the host country, private sector participants, and the global community as a whole. Benefits at the global level include reducing the overall global cost of GHG reductions while promoting sustainable development. Benefits accruing to participants within host countries include technology transfer, investments, local environmental and human health benefits, local economic benefits, sustainable development, and the opportunity to influence the future of JI.

---

[22] Estimated emission reductions were derived using data on the numbers and types of buses initially in the Hungarian fleet; emissions data for vehicle and engine types were derived from a standardization emission test, fuel consumption data, and an estimated average of 65,000 kilometers driven per year. The full project description of the RABA/Ikarus Compressed Natural Gas Project is posted on the UNFCCC Website at http://www.unfccc.int/program/aij/aijact/hunnld01.html.

[23] http://www.unfccc.int

[24] The CCAP is a set of 44 actions developed by the Clinton Administration in 1993 to achieve the stabilization of GHGs at 1990 levels by the year 2000. Of the 44 CCAP actions, only 13 are unrelated to the issues of energy combustion and carbon dioxide, and many establish voluntary initiatives to encourage private/public partnerships for the promotion of GHG reduction activities. http://www.gcrio.org/USCCAP/toc.html.

Benefits to participants outside the host countries (that is, the project developers and those organizations that provide the technology) include:

- Market access: JI pilot projects provide entrée into energy and environmental markets in host countries. Participants may also be eligible for host country assistance in terms of relaxed permitting, reduced import restrictions, local content requirements, and/or tariffs.
- Lower cost of "green" technologies: USIJI enhances the competitiveness of "green" technologies by accelerating the exploitation of applications worldwide and further reducing the marginal cost of production.
- Enhanced prospects for financing: USIJI expands partnership opportunities by providing greater visibility and credibility to the potential project which can, in turn, increase the depth of credit-worthiness associated with the project.
- Reduced risk: Greater security of investment in foreign countries.
- Expanded knowledge of the JI option: Provides participants an opportunity to influence the direction and structure of JI beyond the pilot phase by demonstrating the potential for international collaboration to resolve environmental problems.
- Public recognition: Establishes a public record of GHG-reducing activities.
- International credibility: Establishes a track record in international markets by working with governments, businesses, and organizations in foreign countries.

Any U.S. private sector firm, non-governmental organization (NGO), government agency, or individual is eligible to submit a project proposal to USIJI.[25] Proposals must be submitted in partnership with foreign host country participants, including any citizen or entity recognized by a host country, which has signed, ratified or acceded to the UNFCCC. Determination of the acceptability of the projects is made by an eight-member Evaluation Panel, co-chaired by the Environmental Protection Agency and the Department of Energy with representation by the U.S. Agency for International Development, and the Departments of State, Agriculture, Commerce, Interior, and Treasury. The goal of USIJI is to promote a broad range of projects to test and evaluate methods to measure, track, and verify costs and benefits of accepted projects. Projects accepted into the USIJI program are evaluated against nine criteria and four other areas of consideration (see Appendix 4). These criteria are intended to identify those projects that support the development goals of the host country while providing GHG benefits beyond those that would occur in the absence of the joint implementation activity.

The USIJI criteria have been formulated to ensure that accepted projects will produce real and measurable net emission benefits. To meet these criteria, the project developers must evaluate their projects for expected impacts on GHG emissions. This involves establishing a reference case for what emissions would have been absent the project, and an estimate of what emissions are likely to be with the project. The difference between these two provides an estimate of expected emission reductions attributable to the project. See also Chapter 4 for a detailed case study of how to calculate the reference case and project-related emissions. Before submitting the proposal, parties must also agree upon how emission reductions will be allocated among them and develop procedures that ensure that the GHG accomplishments are not reversed over time.

Finally, USIJI projects must also provide a carefully planned procedure for monitoring and verification (M&V) of emission reductions. A monitoring plan addresses such standard issues as the type of data

[25] For further information on the USIJI program or the project selection criteria, contact USIJI, 1000 Independence Avenue SW, Washington DC 20585, USA, Tel: (1-202) 586-3288, Fax: (1-202) 586-3485 or -3486.

gathered and the frequency of sampling. A monitoring plan should also discuss the stability of the monitoring institution and the verification of the monitoring process itself.

It is expected that the criteria for acceptance into the USIJI program may change to incorporate the application criteria of any future project-based market programs for controlling emissions.

2.2.2 Other Potential Technology Transfer Mechanisms

In December 1997, the Third Conference of the Parties (COP-3) to the UNFCCC met in Kyoto, Japan and adopted the Kyoto Protocol. The Kyoto Protocol sets legally binding GHG emission reduction limits for individual nations to be achieved during the commitment period of 2008 to 2012. As part of the initial agreement on the Protocol, the U.S. committed to reduce emissions to seven percent below 1990 levels.

The Kyoto Protocol will become legally binding when 55 countries, accounting for at least 55 percent of industrialized countries' GHG emissions in 1990 have ratified the agreement. As of March 2001, 84 countries, including the United States, have signed the Protocol, and 33 have provided ratification or accession.[26] The United States has not yet ratified the Protocol and the Administration recently announced that it was opposed to the Protocol as it fails to adequately involve developing countries in any binding reduction activities. Thus it will be very difficult to meet the requirements for entry into force of the Protocol. Following these recent developments, it is unclear whether the proposed project-based Protocol mechanisms of JI and CDM will ever be put into practice. However, regardless of the status of the Protocol, it is likely that some sort of mechanism for undertaking and receiving credit for cooperatively implemented emission reduction projects across national borders will be established in the future. To provide guidance on the direction that such mechanisms might take, we have chosen to include a brief discussion of the CDM and JI in this primer.

Because of their focus on project-based emission reductions, the CDM and JI would help facilitate the use of NGV-related GHG emission reduction projects. The CDM allows for jointly implemented projects funded by project developers in industrialized countries (Annex I countries) and hosted in developing countries (non-Annex I countries). JI projects are cooperatively implemented projects between two or more Annex I countries; that is, countries with legally binding emission reduction targets.

The major difference between the proposed JI and CDM of the Kyoto Protocol and the UNFCCC's AIJ Pilot Phase is that only the Protocol allows project developers to receive certified credits for their reduction activities. These credits are expected to provide significant economic incentives for the development of a wide variety of emission reduction projects, including NGV projects. For countries that lack experience with NGV vehicles, the credits to be awarded under such market-based mechanisms as the CDM and JI may help to overcome existing economic and institutional barriers to NGV deployment. The AIJ Pilot Phase, on the other hand, does not provide AIJ project developers with credits for their emission reductions. We will describe the CDM and JI in more detail in the following subsections.

The Clean Development Mechanism (CDM)

A Clean Development Mechanism (CDM) project is defined in Article 12 of the Kyoto Protocol as a project between an industrialized and a developing country that provides the developing country with project financing and technology while assisting the industrialized country in meeting its emission reduction commitments. A major requirement of projects developed under the CDM is that these projects have to further the sustainable development goals of the host country. In addition, CDM projects must

[26] Accession is the act whereby a state accepts the offer or the opportunity to become a party to a treaty already negotiated and signed by other states. It has the same legal effect as ratification, http://www.unfccc.int.

involve activities that would not have happened in the absence of the project and the projects should result in real and measurable emission reductions. Under the CDM, projects yield certified emission reductions (CERs), which are accrued by the industrialized country and may be applied towards its emission reduction goals. CERs are verified and authenticated units of GHG emission reductions from mitigation and possibly also sequestration projects. They are issued pursuant to review and certification by an operational organization to be defined by the Conference of the Parties (COP). Discussions at the Fourth Conference of the Parties (COP-4) in Buenos Aires, Argentina divided the project review process into two elements: project certification and project verification. Certification is to take place prior to project implementation by pre-approved project certifiers qualified to evaluate the emission baselines chosen and the reduction estimation methodology used. Project verification is to be carried out over the life of the project by independent auditors approved by a CDM Executive Board or some other project entity yet to be agreed upon by the Parties. These auditors would confirm that the claimed emission reductions have occurred.

Joint Implementation

Joint Implementation (JI) involves project activities undertaken by two or more countries with legally binding emission targets. This group of countries is known as the Annex I countries and is made up mostly of industrialized countries and some countries with economies in transition. The rules and procedures for determining the emission reductions associated with a JI project may or may not be similar to those established for CDM projects. Currently, developing countries are arguing that the same rules should apply to both JI and CDM projects while industrialized countries want the rules for JI projects to be less stringent than those for CDM projects. The latter argument is based on the fact that Annex I countries already have binding national emission reductions targets under the Protocol. Reduced accuracy in the estimation of JI emission reductions would in effect be discovered and corrected through the national emission inventories, and national emission reduction targets, established for these countries. Developing countries, on the other hand, do not have binding emission reduction targets, making it crucial to ensure the environmental credibility of the projects approved under CDM. Because of this difference, the Parties may agree to lower the project design requirements for activities seeking JI certification.

2.2.3 Application Criteria for Developing GHG Reduction Projects

There are several criteria that must be met before projects may receive credit under the AIJ Pilot Phase and the proposed JI/CDM options of the Kyoto Protocol. The UNFCCC criteria for participation in the AIJ Pilot Phase are very general; however, the various national programs that have set up AIJ offices to evaluate, approve, and implement AIJ projects have elaborated on these criteria to suit national priorities and development circumstances. In general, AIJ projects must:

1. Include approval from host and sponsor countries: Both of the countries involved in a jointly implemented project must have provided official recognition and approval of the project in question in order for it to be recognized as an AIJ project.
2. Ensure additionality: The activity must result in real, measurable, and long-term reductions in net GHG emissions that would not have occurred in the absence of such an activity.
3. Exclude Official Development Assistance (ODA): The activity should be financed outside current ODA flows.
4. Include an estimate of emissions and emission reductions with and without the project (i.e. an emission baseline) to calculate net GHG emission reductions.
5. Account for other project impacts: Most AIJ programs also require that project proposals account for other positive and negative impacts of the project, including economic and environmental impacts. Moreover, possible leakage should be addressed.

6. Present a monitoring and verification plan: Project developers have to provide a plan for monitoring and verifying emissions during the life of the project.

As status of the Kyoto Protocol has not yet been agreed upon, the final guidelines for project development and approval under the CDM and JI have not yet been completed. Given this uncertainty, it is unclear what programs and procedures will actually be implemented to facilitate project-based market activities. However, it is likely that any future program will entail many of these same requirements.

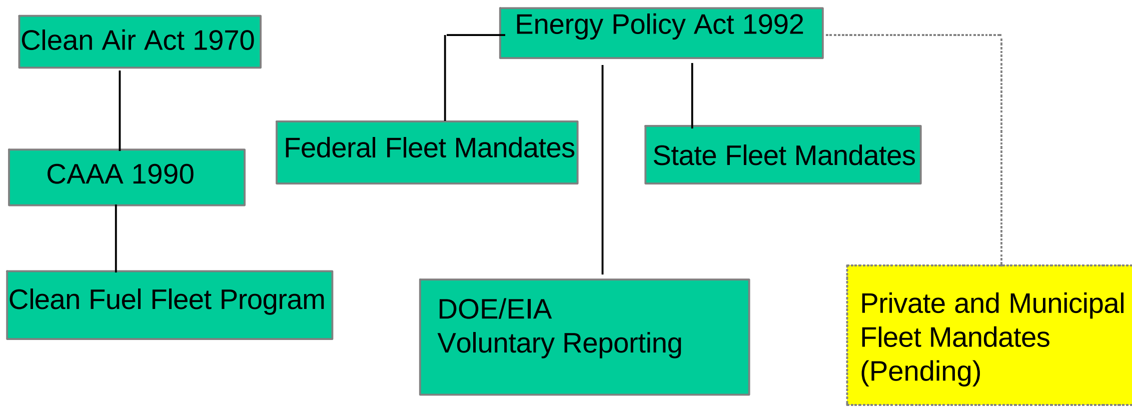
2.3 U.S. Framework for Promoting the Use of NGVs

In addition to potential international regulation of GHG emissions, there are domestic regulations that promote the use of NGVs (see Figure 5). The two principle laws that encourage the use of NGVs are the Clean Air Act of 1970, its subsequent amendments of 1990, and the Energy Policy Act of 1992 (EPAct). The Clean Air Act of 1970 focused on local air quality standards and did not address GHGs. By 1990, concern about increasing atmospheric concentrations of GHGs was reflected in the Clean Air Act Amendments of 1990 (CAAA90) with references to the importance of reducing GHGs in addition to other airborne pollutants. However, sections covering vehicle emissions still emphasized local air quality only. The CAAA90 required a phased reduction in vehicle emissions of regulated pollutants and authorized the U.S. Environmental Protection Agency to set National Ambient Air Quality Standards (NAAQS) and designate standards to mediate air pollutant levels. It is only recently that the related GHG benefits have gained prominence and no specific initiatives have yet been passed to regulate these gases.

Efforts to increase the use of AFVs embodied in EPAct also did not focus directly on reducing GHG emissions but rather on decreasing domestic demand for oil and reducing dependence on foreign imports. However, EPAct did include a more formal recognition of the importance of reducing GHG emissions. Section 1605 of EPAct established the Voluntary Reporting of Greenhouse Gases Program. The implementation of this program led to the creation of a database where reductions in GHG emissions from the use of AFVs could be reported and the data preserved. A more detailed discussion of the provisions within the Clean Air Act and EPAct encouraging the use of NGVs appears below.

In addition to the regulatory legislation cited above, the U.S. government has several programs and initiatives for promoting the use of NGVs. These programs include the National Energy Technology Laboratory's Strategic Center for Natural Gas (SCNG), DOE's Clean Cities Program, and the Department of Transportation's Center for Global Climate Change and the Environment. A more detailed description of these programs appears in section 2.4.

Figure 5. U.S. Legislative Framework for Promoting the Use of NGVs



2.3.1 The Clean Air Act of 1970 and the Clean Air Act Amendments of 1990

The Clean Air Act (CAA) is a comprehensive Federal law that regulates air emissions from area, stationary, and mobile sources.[27] The Act was passed in 1970 to improve air quality nationwide, and authorized the U.S. Environmental Protection Agency to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment. The goal of the Act was to set and achieve NAAQS in every state by 1975. The setting of maximum pollutant standards was coupled with direction to the states to develop state implementation plans (SIPs) applicable to appropriate industrial sources in each state. The CAA was amended in 1977, largely to set a new timetable for achieving attainment of NAAQS since many areas of the country had failed to meet the earlier deadlines.

A more comprehensive set of amendments to the Act was signed into law in 1990 (CAAA90), in large part to meet insufficiently addressed problems such as acid rain, ground-level ozone, stratospheric ozone depletion, and air toxics. CAAA90 also focused on reducing mobile source pollutants, by establishing tighter pollution standards for emissions from passenger cars, trucks and buses, as well as off-road engines and vehicles. The standards were intended to reduce tailpipe emissions of hydrocarbons, carbon monoxide and nitrogen oxides on a phased-in basis beginning with model year 1994.

The CAAA90 also established the Clean Fuel Fleet (CFF) Program, which, perhaps more than any other CAAA program, is cited as a program that will lead to greater use of alternative fuel vehicles (AFVs). The program focuses on vehicle fleets because, on the per vehicle basis, fleet vehicles have more of an opportunity to produce a positive impact on air quality than non-fleet vehicles, and because fleets represent a very effective mechanism to introduce clean fuel technology to the market. It is expected that this program will affect approximately 35,000 fleets and result in the introduction of about one million clean-fueled vehicles nationwide by 2010.[28]

Starting in model year 1999 (October 1998), publicly and privately owned fleets of ten or more automobiles were required to acquire clean-fuel vehicles (CFVs) when they replaced their vehicles. The program initially required that 30 percent of new light-duty vehicles were CFVs. Fifty percent of newly

---

[27] The complete table of contents of the Clean Air Act as amended in 1990, and a printout of Title II (the "National Emission Standards Act." [42 U.S.C. 7401 nt]), Part C, Clean Fuel Vehicles, can be found at: http://www.epa.gov/oar/caa/contents.html and http://www.epa.gov/oar/caa/contents.html#titleii.
[28] Wisconsin Department of Natural Resources, http://www.dnr.state.wi.us/org/aw/air/reg/cff/cff.htm.

acquired medium- and heavy-duty vehicles (i.e., 8,500 - 26,000 gross vehicle weight) were required to be CFVs.

The CAAA defines "clean fuels" as natural gas, ethanol, methanol or other alcohols; mixtures containing 85 percent or more methanol, ethanol or other alcohols; reformulated gasoline and diesel; propane; electricity; and hydrogen. Therefore, the purchase of NGVs by a fleet operator falling under these requirements would fully satisfy the requirements of the law.

The CAAA90 identified 22 non-attainment areas in the CFF Program. Fourteen of these areas have asked the U.S. Environmental Protection Agency (EPA) to allow them to adopt other measures, as long as these programs provide equivalent or greater reductions of hydrocarbons, carbon monoxide, and nitrogen oxides. The current list of areas that have adopted regulations for the CFF program includes Atlanta, GA; Baton Rouge, LA; Chicago, IL; Denver-Boulder, CO; Gary, IN; Milwaukee-Racine, WI; North Carolina; Virginia and Washington, D.C. [29]

Although the CAAA90 does not require automotive manufacturers to produce alternative-fuel vehicles, the number of NGVs is increasing significantly because of the law's tougher emission standards. The introduction of more expensive emission reduction technologies on gasoline vehicles is expected to make NGVs more economic, since they are generally expected to meet the new standards with little or no major modifications. Laws that focus on vehicle emission reduction have served to educate millions of Americans on the importance of controlling motor vehicle pollution. Many air-quality officials are now looking for ways to increase the number of NGVs in their states.[30]

2.3.2 Energy Policy Act of 1992 (EPAct)

The Energy Policy Act of 1992 (EPAct) is another piece of domestic legislation that promotes the use of NGVs. Although EPAct focuses primarily on reducing energy demand and dependence on foreign oil imports by encouraging the use of domestically produced fuels, it contains both mandates and incentives for the use of alternative fuels in vehicles.[31]

Under EPAct, "alternative" fuels include natural gas, methanol, ethanol, propane, hydrogen, coal-derived liquids, biological materials, and electricity. EPAct also includes any other fuel that the Secretary of Energy finds to be substantially non-petroleum and which would yield substantial energy security and environmental benefits.

The Energy Policy Act required federal fleets to begin purchasing AFVs in fiscal year 1993. Regulations issued by the Secretary of Energy required state fleets and alternate fuel providers to begin purchasing AFVs in model year 1997. Under EPAct, the Secretary of Energy was given the opportunity to justify a mandate for private and local fleets. An ongoing rulemaking process may lead to final regulations in this area. If regulations are promulgated as currently formulated, beginning with model year 2002, 20 percent of new light duty vehicles must be AFVs, increasing to 70 percent by 2005.

Table 5 summarizes the annual purchase requirements for Federal and State fleets, alternate fuel providers, and private and municipal fleets.

---

[29] International Association for Natural Gas Vehicles, http://www.iangv.org/html/sources/qa.html#meet.
[30] *Alternative Fueled Vehicles for State and Fuel Provider Fleets: A Guide for Meeting the Requirements of the Alternative Fuel Transportation Program*, U.S. Department of Energy. http://www.afdc.doe.gov/pdfs/newguid.pdf.
[31] See also the final rules for the Alternative Fuel Transportation Program, http://www.afdc.doe.gov/pdfs/fprovrule.pdf

Table 5. Alternative Fuel Vehicle Purchase Requirements

Year	Federal (%)	State (%)	Provider (%)	Private* (%)
1997	33	10	30	--
1998	50	15	50	--
1999	75	25	70	--
2000	75	50	90	--
2001	75	75	90	--
2002	75	75	90	20
2003	75	75	90	40
2004	75	75	90	60
2005+	75	75	90	70
* Tentative percentages currently under investigation by DOE.				

Source: DOE, Office of Transportation Technologies, "EPACT/Clean Fuel Fleet Program Fact Sheet," http://www.afdc.doe.gov/pdfs/caaa.pdf.

The percentages in Table 5 generally apply to small vehicles in large fleets operating in cities with a 1980 population of at least 250,000. Covered vehicles are those up to 8,500 pounds gross vehicle weight (GVW), which include passenger cars, pickup trucks and vans. Fleets must have at least 20 vehicles that can be centrally fueled; fleet owners with less than 50 vehicles nationwide are exempt from EPAct AFV requirements. For non-government fleets, the penalties for violation start at $5,000 and increase to $50,000 for repeat violations.

EPAct also offers a number of tax incentives in the form of Federal tax deductions for the purchase of AFVs, including NGVs, as detailed in Table 6. They include $2,000 to $50,000 for the vehicle (depending on size) and up to $100,000 for a fueling station. These tax deductions apply to property placed in service after June 30, 1993. The vehicle deductions apply to the incremental cost of an AFV over its gasoline or diesel counterpart, including either factory-made vehicles or after-market conversions. The facility deduction applies to each fueling station installed by a business at a single location.

Table 6. Alternative Fuel Vehicles Maximum Tax Deductions

Vehicle (up to 10,000 lbs. gvw)	$2,000
Vehicle (10,001 to 26,000 lbs. gvw)	$5,000
Truck or van (over 26,000 lbs. gvw)	$50,000
Bus (seating capacity of 20 or more adults)	$50,000
Alternative Fuel Refueling Facility	$100,000

Source: Internal Revenue Code Sec. 30 and 179A as cited in U.S. DOE, Office of Transportation Technology, ATA Foundation, Alternative Fuels Task Force, "Alternative Fuels Tax Guide for 1999," http://www.afdc.doe.gov/documents/fed-tax.html.

Other provisions of EPAct that may encourage the use of alternative fuels include:

- Up to $30 million/year to assist in the purchase of alternate fuel transit buses and school buses;
- $25 million/year for low-interest loans for the purchase of AFVs;
- State and local incentive programs, including $10 million/year to assist states in acquiring AFVs;
- Exemption for vehicular natural gas from certain Federal and State regulations;

- Certification of training programs for alternate fuel vehicle technicians; and
- Public information programs.

A fleet owner may be required to comply with either or both of the Clean Air Act Amendments of 1990 and the Energy Policy Act of 1992 if the fleet contains the minimum number of non-excluded vehicles that operate in an area targeted by the law. The definition of minimum number and which vehicle categories and operating conditions are excluded from consideration are somewhat different for each law. The geographic areas covered by each law differ as well. The areas covered by the CAAA90 are a small subset of the areas covered by EPAct.[32] Appendix 1 offers a tabular comparison of the provisions of EPAct with those of the CAAA90's Clean Fuel Fleet Program. This comparison may assist fleet owners in determining what rules affect their fleets.

2.3.3 DOE/EIA Voluntary Reporting of Greenhouse Gases Program

The Voluntary Reporting of Greenhouse Gases Program, created under Section 1605(b) of EPAct, affords an opportunity for any company, organization or individual to establish a public record of their GHG emissions, reductions, or sequestration achievements in a national database. Reporters can gain recognition for environmental stewardship, demonstrate support for voluntary approaches to achieving environmental policy goals, support information exchange, and inform the public debate over GHG emissions.

Managed by DOE's Energy Information Administration, the Voluntary Reporting of Greenhouse Gases Program first began accepting reports on GHG reduction activities during calendar year 1995. Data from the most recent reporting cycle, covering activities through 1999, were released by EIA in January 2001 and include considerable information on real-world NGV projects. Seventeen NGV projects were reported to the program. Appendix 2 offers summary information on these projects, including the entities that undertook and reported the project, the name, scope and general description of each project, and the methods used to estimate the achieved greenhouse reductions. The data reported to the Program is publicly available on DOE's website and may be useful for educational and project replication purposes.[33]

2.4 Other Programs for Promoting the Use of NGVs

2.4.1 DOE's National Energy Technology Laboratory (NETL) Strategic Center for Natural Gas (SCNG) and Office of Fuels and Energy Efficiency

Noting that "Our Energy Information Administration tells us that natural gas will be the 'fuel of choice' for the next 10 or 20 years, perhaps longer," former Secretary of Energy Bill Richardson established the Strategic Center for Natural Gas within NETL in December of 1999. The Secretary also reaffirmed that "We are counting on it [the Center] to meet many of our energy goals <u>and</u> many of our environmental goals." He charged NETL with creating a single center within DOE to look out for the future of natural gas "from borehole to burnertip." With its 60-year history in gas production, processing and utilization, NETL was uniquely qualified to serve as the focus for DOE's natural gas research, development, and demonstration activities and was asked by the Secretary to "look to the big picture and devise the bold ideas that allow the full potential of natural gas to be achieved."

---

[32] Energy Policy Act of 1992, Title V – Availability and Use of Replacement Fuels, Alternative Fuels, and Alternative Fueled Private Vehicles, Section 502: http://energy.nfesc.navy.mil/docs/law_us/92epact/hr_0500.htm, and Title XVI - Global Climate Change: http://energy.nfesc.navy.mil/docs/law_us/92epact/hr_1600.htm
[33] See http://www.eia.doe.gov/oiaf/1605/frntvrgg.html for more information.

NETL also contributes to its commitment to the future of natural gas with the Office of Fuels and Energy Efficiency. This office operates programs in natural gas processing, transportation fuels and chemicals, advanced fuel research, and energy conservation programs. These programs develop economically sound technologies to provide cleaner transportation fuels, lower cost chemical manufacturing processes, and environmentally responsible use of fossil fuels. They also promote energy efficiency and sustainable development. The Office of Fuels and Energy Efficiency is implementing these goals by providing research and technical assistance to industry, government-industry partnerships, and other DOE offices.

A fundamental mission of DOE is to secure increased, reliable, and low-cost energy supplies while protecting the environment. Increased utilization of natural gas is a key element in achieving this goal. Therefore, NETL works with industry, other DOE offices, and the National Economic Council of the White House to develop and implement a strategic plan for natural gas that promotes expanded gas use. The integrated plan removes redundancies and fills gaps in the current suite of DOE activities, and it ensures that all of DOE's work makes sense in the context of the entire natural gas system.

NETL focuses research into exploration and production, transmission and distribution, markets and end-use technologies as well as the policy and regulatory framework of the nation's natural gas systems. While transportation is one of the smaller applications of natural gas use on the United States, NETL is committed to promoting and advancing NGV use and technology. One specific area of NETL focus is in gas-to-liquid (GTL) conversion research. The goal is to develop and demonstrate advanced technologies and processes for economic conversion of methane to liquids that can be used as fuels or chemical feedstock. This will increase the supply of liquid transportation fuels, thus reducing the demand for crude oil-derived transportation fuels.

2.4.2 U.S. Department of Energy Clean Cities Program

The Clean Cities Program is sponsored by DOE and is designed to encourage the use of AFVs and their supporting infrastructure. By encouraging AFV use, the Clean Cities program helps to achieve energy security and environmental quality goals on local, national, and international levels. The Clean Cities program takes a voluntary approach to AFV development, working with coalitions of local stakeholders to help develop local strategies and initiatives to integrate AFVs into the local transportation sector. There are currently 77 Clean Cities in the United States; 3 border programs with the cities of El Paso, Texas and Juarez, Mexico; Detroit, Michigan and Toronto, Canada; and Grand Forks, North Dakota and Winnipeg, Canada; and a separate international program in Santiago, Chile.

The DOE Clean Cities International Program began as a result of the Hemispheric Energy Symposium held in October 1995 in follow-up to the December 1994 Summit of the Americas. The Hemispheric Energy Symposium was held in order to begin the implementation process of the Summit of the Americas Plan of Action pertaining to energy cooperation and sustainable development. Hemispheric Clean Cities was one of 40 initiatives established.

Information posted on the Clean Cities Website provides a useful resource for a project developer requiring background information on NGVs while preparing an NGV GHG emission reduction project.[34] Project developers may also contact the Clean Cities Hotline at 1-800-CCITIES for additional information.

[34] http://www.ccities.doe.gov

2.4.3 U.S. Department of Transportation Programs

In May 1999, the U.S. Department of Transportation announced that it was forming the Center for Global Climate Change and Environment to conduct scientific research on emerging technologies and alternative fuels to deal with carbon dioxide emissions from transportation sources. To address transportation issues related to climate change and global warming, officials from the Department said that the research center would focus on new technologies to achieve higher fuel efficiency, tax credits for fuel-efficient cars, changes in travel behavior, and transportation planning as part of community development. During the opening session the former transportation secretary Rodney Slater noted that transportation accounts for 26 percent of U.S. GHG emissions and that the new center would work closely with the Environmental Protection Agency and the Department of Energy to promote the development of low-emitting transportation technologies.

3. Natural Gas Vehicles and GHG Emissions

3.1 Introduction

This chapter discusses issues related to the estimation and documentation of GHG reduction benefits and/or penalties of NGV projects. The international program where project developers can apply for participation is the existing UNFCCC AIJ Pilot Phase. Other market-based mechanisms for crediting project-level GHG reduction efforts have been proposed. These include provisions for emissions trading and the introduction of new initiatives, such as CDM and JI, whereby investors and polluters can obtain credit for GHG reduction activities undertaken outside U.S. borders. Although the procedures and framework for responding to the issue of global climate change are still evolving, it is likely that any future domestic or international GHG reduction efforts will rely heavily on such market-based procedures. Thus, experience with and procedures for developing project-based GHG reduction projects in the transportation sector will be important to the success of market-based initiatives. However, in order to earn credit under these initiatives, projected emissions and emission reductions over the life of the transportation project have to be estimated and quantified. This includes estimating projected GHGs with and without the project in order to derive the net emission benefits of the activity in question. The specific requirements and procedures for estimating GHG emission reductions are described further in Chapter 4 of this Resource Guide.

As natural gas is a cleaner burning fossil fuel, the NGV population is growing rapidly in many parts of the world. However, to date, only a few projects deploying NGVs have been developed and implemented specifically with the purpose of reducing GHGs and gaining approval under the UN-sponsored GHG reduction programs. Thus, experience with quantifying, evaluating, and verifying GHG emission reductions from NGV projects is almost non-existent. This is a problem, as there are many issues unique to the transportation sector, which should be resolved before adequate guidelines for transportation-related projects can be developed. In the case of the electricity and forestry/land use sectors, the approval of a large number of AIJ projects has facilitated the establishment of a vast body of literature on, and methodologies for, developing and evaluating GHG mitigation projects. This experience has provided reference material for the Parties to the UNFCCC as they have worked to establish the methodological procedures for project development under the CDM and JI – both in the case of establishing project-specific and multi-project emission baselines**.** However, the limited experience with transportation projects means that less attention has been paid to resolving key issues for this sector. Issues that will need to be resolved include:

- The development of procedures for an accurate and cost-effective estimation of emission reductions from a dispersed number of emissions sources;
- Guidance on which natural gas-related GHG emissions to include in the emission baseline;
- Reducing the high transaction costs associated with validation, monitoring, verification, and certification of transportation projects; and
- A determination of whether to include full fuel cycle data or only tailpipe emissions in the estimation of emission benefits.

The importance of each of these issues will be examined further in the following discussion.

This chapter provides an overview of the available literature and models for estimating NGV-associated GHG emissions. In particular, the overview will focus on: 1) the status of domestic and international transportation-related GHG reduction activities; 2) the various GHGs associated with NGV projects; 3) sources of emissions during fuel production and vehicle operation; and 4) transaction costs involved with estimating and documenting emission reductions. Finally, the chapter concludes with a discussion of some of the barriers that may have prevented the development of UNFCCC-related transportation projects in previous years and provides suggestions for overcoming such barriers.

3.2 Projects Deploying Transportation Technologies to Reduce GHG Emissions

Throughout most of the world, numerous projects and policies have been implemented to control and alleviate the problems associated with transportation, including accidents, congestion, and local air pollution. However, there is little international experience with jointly implementing transportation-related projects specifically with the purpose of reducing GHG emissions. Instead, most GHG mitigation initiatives target sectors such as electricity generation, industrial energy use, renewable energy development, or land use and forestry activities. No transportation projects have been developed in anticipation of the CDM, although there is active interest on the part of public and private sector participants in the Clean Cities Santiago Program in Santiago, Chile in creating an NGV project for potential acceptance into the CDM. Of the 144 projects registered with the UNFCCC Secretariat as AIJ pilot projects, only one takes place in the transportation sector.[35] This project, known as the RABA/IKARUS Compressed Natural Gas Engine Bus project, is funded by Dutch investors and hosted in Hungary. The project involves the development and testing of a new CNG engine to be installed by the companies of RABA and Ikarus in new buses. These buses will replace the purchase of 1,500 diesel buses.[36]

In the U.S., the number of voluntary actions to reduce GHG emissions in the transportation sector is also relatively low. In 1999, there were 73 transportation GHG emission reduction projects reported to the DOE Voluntary Reporting of Greenhouse Gases Program, a small number compared to the 435 electricity generation, transmission, and distribution projects reported for that same year.[37] Nearly half (47) of these transportation projects involved AVFs; 17 involved the use of NGVs. Five utilities reported operating fleets of more than 100 CNG or dual-fuel CNG/gasoline vehicles in 1999. The AFV project developers reported an average estimated emission reduction of 783 metric tons of CO_2 equivalent. Concerned with the lack of transportation sector projects, national joint implementation offices have been promoting their development. For example, DOE issued a grant in the fall of 2000 to the Washington D.C.-based Center for Sustainable Development in the Americas (CSDA) to create an AIJ project using NGVs in Santiago.

3.3 Studies on GHG Emission benefits from NGVs

Few studies have been conducted to estimate emissions and energy use during the entire fuel cycle of alternative fuel vehicles, including NGVs. The most comprehensive fuel cycle analysis of NGVs has been undertaken by Michael Wang of Argonne National Laboratory.[38] In 1996, Wang developed a spreadsheet-based fuel-cycle model to enable researchers to evaluate fuel-cycle energy and emissions impacts of various transportation technologies, to test their own methodologies and assumptions, and to make accurate comparisons of different technologies. The model is known as the Greenhouse Gases,

---

[35] http://www.unfccc.int/program/aij/aijproj.html. As of September 18, 2000, the UNFCCC Secretariat website listed 50 registered and approved renewable energy AIJ projects, 13 forest preservation projects, 2 afforestation projects, 2 agriculture projects, 61 energy efficiency projects, 9 fuel switching projects (including the transportation project), and 7 fugitive gas projects.

[36] AIJ Uniform Reporting Format: Activities Implemented Jointly under the Pilot Phase. The RABA/IKARUS Compressed Natural Gas Engine Project, http://www.unfccc.int/program/aij/aijact/hunnld01.html.

[37] http://www.eia.doe.gov/oiaf/1605/frntvrgg.html. See also Appendix 2 for a description of NGV projects reported to the program in calendar year 2000.

[38] Michael Q. Wang, "Fuel-Cycle Analysis of Transportation Fuels: Development and Use of the GREET Model." Presentation for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies.* San Diego, CA, May 10, 2000.

Regulated Emissions, and Energy Use in Transportation (GREET) model. It estimates the full fuel cycle emissions and energy use associated with various transportation fuels and advanced light-duty vehicle technologies.[39] It calculates fuel-cycle emissions of criteria pollutants (volatile organic compounds, carbon monoxide, nitrogen oxides, particulate matter, and sulfur oxides) and three GHGs (carbon dioxide, methane and nitrous oxide). Researchers and project developers can input individual vehicle data into the model to obtain emissions results for specific vehicle types.

It should be emphasized that the GREET model is developed based on U.S. energy data. The results of the model will therefore be less accurate for other countries with a different energy mix. Project developers outside the U.S. should only use this model as guidance for estimating the potential emission benefits of specific vehicle types. For accurate country-specific results, a similar model would have to be developed taking local energy factors of each individual country into account, or relevant data could be put into the GREET model to modify the necessary background assumptions.

3.4 GHG Emissions Associated with Natural Gas Vehicle Projects

Greenhouse gas emissions from the use of natural gas vehicles include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).[40] The amount of GHG emissions produced per unit of energy depends on the carbon content of the fuel, the leakage during fuel production and transportation, and the efficiency of the combustion process of each vehicle type and model. Because of these variables, it is difficult to make generalizations about the potential emission impacts of deploying NGVs. Nonetheless, some overall suggestions can be provided to help specify the emission benefits of various vehicle types, and general guidelines can be developed for which emissions sources to include and quantify during baseline development.

In the following sections, the potential emission impacts of NGV projects are discussed and suggestions for how to develop a project emission baseline are provided.

3.4.1 Carbon Dioxide Emissions

Carbon dioxide (CO_2) emission benefits of NGVs vary depending on the type of fuel and vehicle model being replaced. In general, light-duty NGVs have a significant CO_2 advantage relative to conventionally fueled vehicles (gasoline and diesel) (see Figures 6 and 7). For similar engine combustion efficiencies in light-duty vehicles, natural gas typically has a 20 to 40 percent tailpipe CO_2 emissions advantage versus conventional fuels.[41] Compared to gasoline, the CO_2 production from combustion of CNG and LNG is relatively low, due to the smaller carbon-to-hydrogen ratio characterizing natural gas.

However, when natural gas vehicles are compared to diesel-fueled vehicles, the CO_2 benefits are not as significant – even though the carbon content of diesel is much higher. Diesel vehicles typically result in lower energy consumption than NGVs, because diesel engines have a relatively high efficiency. The improved energy consumption of diesel fuel vehicles offsets some of the CO_2 benefits derived from the lower carbon content of natural gas. This is particularly relevant for medium- and heavy-duty vehicles.

---

[39] Currently there are no similar models for heavy-duty vehicles.

[40] Other emissions associated with natural gas include carbon monoxide and non-methane hydrocarbons. This guidebook will not discuss carbon monoxide and non-methane hydrocarbons because these gases are not included in the Kyoto Protocol as gases to be limited through binding emissions targets. Nitrous oxide is not considered because of the lack of reliable emissions data for this gas.

[41] James McCarthy and Sean Turner, "Natural Gas Vehicles and Greenhouse Gas Emissions." Presentation for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies*. San Diego, California, May 10, 2000.

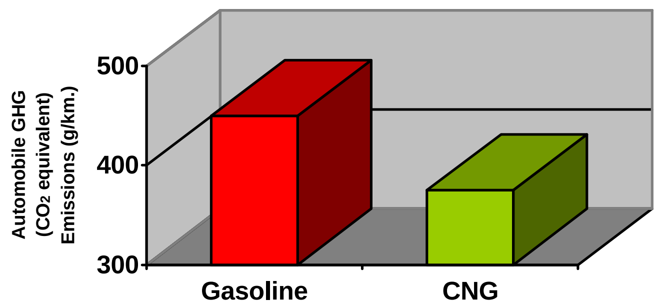
To estimate the net emissions difference, it would be necessary to obtain information about the specific combustion efficiency of both the diesel and natural gas vehicles under consideration. If the new NGV is considerably more efficient than the diesel vehicle to be replaced, the project will still result in significant CO_2 emission reductions.

3.4.2 Methane Emissions

Studies of NGV-related GHG emissions often refer only to CO_2 emissions. Methane should also be included in these studies, however, as it is the primary component of natural gas and makes up a much more potent greenhouse gas than carbon dioxide.

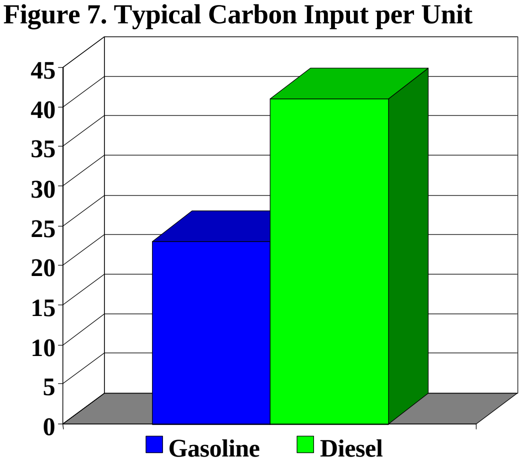
The contribution of CH_4 and other GHGs to global warming is most often expressed in terms of their Global Warming Potentials (GWPs) within a 100 year time period. The GWP is a measure that expresses the relative warming effect of different gases compared to that of a reference gas: in this case CO_2. The index is defined as the cumulative radioactive force between the present and some chosen time horizon caused by a unit mass of gas emitted now, expressed relative to that of CO_2. The most widely accepted estimates for GWPs come from the Intergovernmental Panel on Climate Change (IPCC).[42] These GWPs are used by the international community as guidelines for estimating emission impacts at both the national and project level under the Kyoto Protocol. Likewise, the IPCC's GWP for methane should be used for quantifying emission benefits of NGV projects. According to the IPCC, the GWP of methane, if it is applied to a time horizon of 100 years, is 21 in terms of its ability to trap heat within Earth's atmosphere. This means that one ton of methane is equivalent to 21 tons of CO_2 (see Table 7). These numbers indicate that a small amount of

Figure 6. GHG Benefits of Natural Gas Vehicles



Source: Michael Q. Wang, "Fuel-Cycle Analysis of Transportation Fuels: Development and Use of the GREET Model." Presentation for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies*. San Diego, CA, May 10, 2000.

Figure 7. Typical Carbon Input per Unit



Source: Michael Q. Wang, *GREET 1.5 – Transportation Fuel-Cycle Model: Volume 1 Methodology, Development, Use and Results.* Argonne National Laboratory, August 1999.

[42] The Intergovernmental Panel on Climate Change (IPCC) is the scientific and technological advisory body to the UN Framework Convention on Climate Change (UNFCCC). See Chapter 2 for more information on the UNFCCC and the Kyoto Protocol.

CH_4 emissions can have a relatively large influence on the emission impacts of an individual vehicle project.

Table 7. Global Warming Potential of Greenhouse Gases[43]

Time Horizon			
Gas	**20 Years**	**100 Years**	**500 Years**
CO_2	1	1	1
CH_4	56	21	7
N_2O	280	310	170

It is often claimed that CH_4 emissions represent one of the largest disadvantages of NGVs. As will be discussed below, the presence of CH_4 may even result in an increase in overall project-related GHG emissions in some heavy-duty vehicle applications. Hence, developers of NGV projects should be careful to determine all project-related emissions before deciding to apply for certification as a GHG mitigation project. In particular, project proposals should include a detailed account of project-related CH_4 emissions. If data on CH_4 emissions is unobtainable, project developers should add a CH_4 penalty during the emissions quantification process, for example, by adding a gram/mile CH_4 burden for each gram/mile of CO_2.

3.5 Emission Effects of Engine Efficiency and Vehicle Category

The choice of vehicle model and category, and the efficiency of the engine deployed, has a significant impact on the potential emission benefits of NGV projects. Most of the research on CO_2 and methane emissions associated with NGVs is limited to light-duty vehicles. The GREET model, for example, is based on an analysis of current and advanced light-duty vehicles. The model does not include a similar analysis of heavy-duty vehicles, such as heavy-duty trucks and transit buses. As a result, most of the existing information on emission benefits of NGVs in the U.S. is related to light-duty vehicles. According to the data presented by the GREET model, current NGV technologies lead to an average reduction in GHGs of 7 percent relative to gasoline vehicles.[44] Long-term NGV technologies, still in the research and development stage, are expected to have a 21 percent emissions benefit compared to gasoline vehicles.

Funding has not yet been allocated for a similar GREET study on emissions from heavy-duty vehicles in the U.S. As a result, a discussion of methane impacts from this type of vehicles is difficult. In addition, a comprehensive drive-cycle analysis has not been undertaken for heavy-duty vehicles. This is a problem because information about the drive-cycle impact on vehicle emissions is necessary to estimate the emissions advantage of heavy-duty NGVs relative to conventional vehicles. Most conventional buses rely on diesel for their primary fuel. As diesel engines are considerably more efficient during urban driving cycles – where vehicles remain idle for extended periods of time – the less efficient natural gas buses could result in higher GHG emissions. Thus, although some studies indicate that natural gas-fueled buses have a considerable CO_2 advantage, it is yet unclear whether these buses will have an overall GHG

[43] Intergovernmental Panel on Climate Change, *The Science of Climate Change, Contribution of Working Group I to the Second Assessment of the Intergovernmental Panel on Climate Change.* Cambridge University Press, United Kingdom, 1996.
[44] Michael Q. Wang, *GREET 1.5 – Transportation Fuel-Cycle Model: Volume 1 Methodology, Development, Use and Results.* Argonne National Laboratory, August 1999.

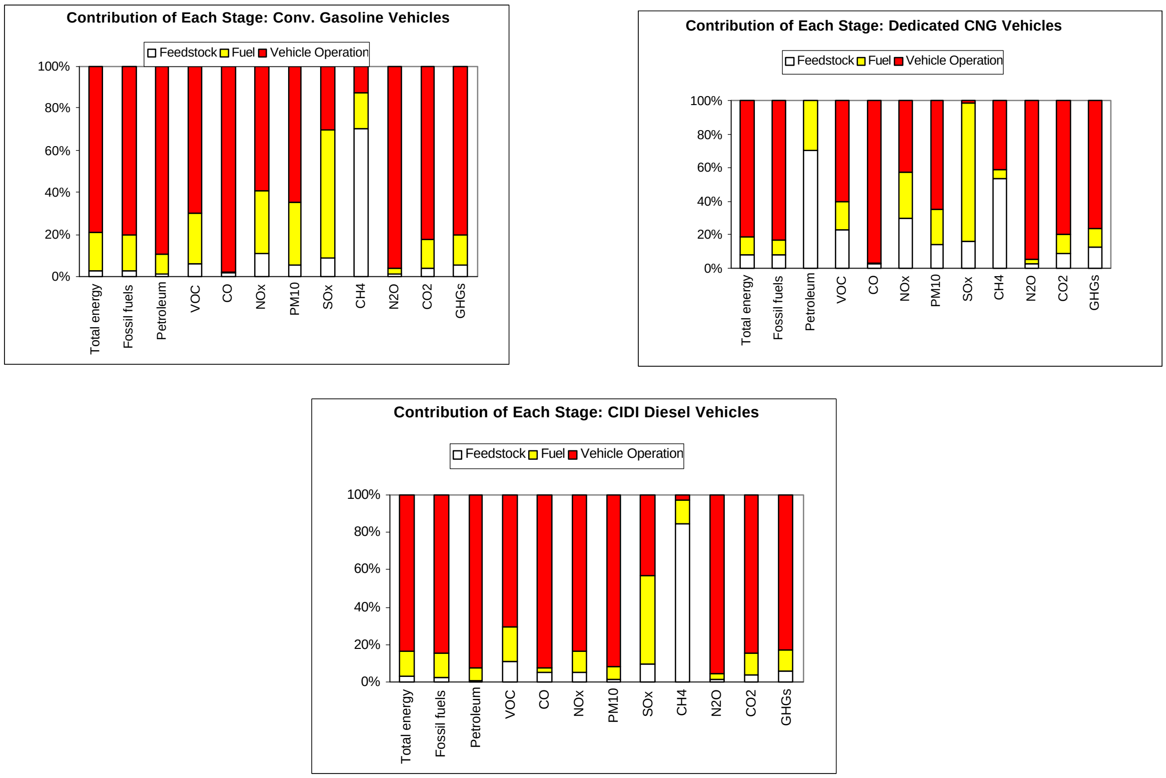
emission benefit, once methane emissions have been taken into account.[45] Project developers wishing to claim emission credits for natural gas bus projects should therefore obtain emissions data directly from the new vehicle manufacturer to determine net emissions of both CO_2 and CH_4. If possible, developers should also examine the driving cycle of the vehicles to be replaced in order to compare the efficiency of the vehicles under consideration. This information will be necessary to obtain a more accurate picture of the potential emission benefits associated with heavy-duty NGV projects.

3.6 Analyzing Tailpipe and Full Fuel Cycle Emission Impacts

Studies of NGVs most often focus on tailpipe emissions. However, the use of vehicle tailpipe data alone does not give a total view of global warming impacts. NGV-related GHG emissions arise from several stages of the fuel cycle, including the production of natural gas, the transmission of the gas to the service station, the compression or liquefaction of the gas, and finally, the combustion of the fuel itself. Figure 8 presents shares of fuel-cycle energy use and emissions by fuel-cycle stage for each combination of fuels and vehicles.[46] These figures, created from results of the GREET model, separate fuel-cycle activities into three stages: feedstock-related, fuel-related, and vehicle operation stages.[47] The figures illustrate that to gain a comprehensive understanding of vehicle emissions, the full fuel cycle from "well to wheel" has to be considered. However, a full fuel cycle analysis will add considerable complexity to the emission baseline estimation process, thereby increasing transaction costs of project development. Although a full fuel cycle analysis may be more inclusive of all potential emission sources, such an analysis will also create more opportunities for error and will require very detailed and costly procedures for data collection.

[45] Based on the results of the GREET model, natural gas-fueled transit buses have an average CO_2 advantage of 8 percent while refuse haulers and line-hauled tractors have an advantage of more than 12 percent relative to similarly ultra-clean diesel vehicles.
[46] Michael Q. Wang, *GREET 1.5 – Transportation Fuel-Cycle Model: Volume 1 Methodology, Development, Use and Results.* Argonne National Laboratory, August 1999.
[47] The feedstock-related stage includes feedstock recovery, transportation, and storage. The fuel-related stage includes fuel production, transportation, storage, and distribution. The vehicle operation stage includes vehicle refueling, tailpipe and operations.

Figure 8. Contribution of Each Stage of the Fuel Cycle to Total Fuel-Cycle Energy Consumption and Emissions



Life cycle emissions, and methodological procedures for collecting this data, also vary from country to country due to differences in energy mix, fuel supply, and transportation characteristics. Many countries in the developing world do not have the required data and institutional resources to undertake an adequate life cycle analysis. This lack of data may limit the ability of project developers to accurately determine the emission benefits of potential NGV projects. One solution may be to exclude the full fuel cycle analysis from the baseline analysis and rely solely on tailpipe emissions data. As illustrated in Figure 8, tailpipe emissions comprise more than 75 percent of total GHGs from gasoline, diesel, and natural gas vehicles. Thus, a simplified baseline estimation process considering only tailpipe emissions will introduce errors no greater than 25 percent into the emission reduction estimates.[48] The effect of this potential error could be mitigated by discounting a similar percentage of the claimed emission reductions, or by adding a predetermined grams/mile increment to the baseline calculation.

As indicated from the results of the GREET model, a baseline analysis based on tailpipe emissions alone will account for a majority of the project-related emissions and will also reduce the transaction costs of

[48] Michael Q. Wang, "Fuel-Cycle Analysis of Transportation Fuels: Development and Use of the GREET Model," and James McCarthy and Sean Turner, "Natural Gas Vehicles and Greenhouse Gas Emissions," presentations for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies*. San Diego, California, May 10, 2000.

project development. During project development under the AIJ Pilot Phase, this approach would probably be adequate. The project development guidelines of the U.S. Initiative on Joint Implementation (USIJI) only require that project developers account for major emissions sources and GHGs when estimating project emission benefits.[49] The developers of the RABA/IKARUS compressed natural gas project in Hungary, which is currently the only transportation project approved under the AIJ Pilot Phase, estimated their baseline scenario by looking at tailpipe emissions only.[50] This project was approved by the Dutch Government.

Project development rules under a future market-based emission reduction scheme with binding reduction targets are likely to be more stringent than the rules of the AIJ Pilot Phase. One of the major methodological issues that will need to be resolved for developing market-based projects in the transportation sector will be whether to accept emission baselines that fail to account for full fuel cycle emissions.

3.7 Barriers to the Implementation of Transportation-Related GHG Mitigation Projects

With the fastest growth rate in GHG emissions, the transportation sector represents a major opportunity for controlling emissions and implementing project-based GHG mitigation projects. To date, however, most of the measures implemented to reduce transportation-related GHG emissions have focused on the development of national policies to control transportation growth and associated emissions. Few attempts have been made to encourage and facilitate project-related activities in the transportation sector.

There are several reasons for the limited number of UNFCCC-related transportation projects. The major challenges facing the transportation sector include: (1) limited experience and methodologies for quantifying, validating, monitoring, and verifying potential emission reductions, (2) a lack of guidance on the emissions sources and data that should be included in the estimation of emission baselines, and (3) high transaction costs associated with developing, evaluating, and verifying transportation projects.

The question of how to quantify, monitor and verify potential emission reductions is significant because unlike other advanced technologies, transportation technologies are dispersed among many small sources; that is, they are normally owned by individual users or on a small- to large-scale fleet basis. As in the case of other advanced technologies, the availability and long-term quality of GHG emission reductions depends on the performance of the equipment in question. However, due to the dispersed ownership and location of the vehicles, it becomes extremely difficult to quickly, efficiently, and cost-effectively monitor and verify potential GHG emission reductions without compromising the credibility of the verification process.

In the literature on GHG mitigation projects, there is also little guidance on which emission sources to include in the estimation of GHG emission reductions (tailpipe versus full fuel cycle) in the transportation sector. Although the most comprehensive measurement of potential emission benefits would be based on a full fuel cycle analysis, the cost of collecting the required data would be prohibitive. However, because most of the data on emission reductions from transportation technologies is based primarily on tailpipe measurements, the true GHG emission benefits of many transportation projects may not at the moment be measured properly.

[49] U.S. Initiative on Joint Implementation, *Resource Document on Project & Proposal Development under the U.S. Initiative on Joint Implementation*, Version 1.1, June 1997.

[50] AIJ Uniform Reporting Format: Activities Implemented Jointly under the Pilot Phase. The RABA/ IKARUS Compressed Natural Gas Engine Project, http://www.unfccc.int/program/aij/aijact/hunnld01.html.

Another significant issue influencing the number of transportation projects is that of transaction costs. The development of transportation-related projects differs from other types of mitigation projects because vehicle ownership and location is often dispersed among many users. In addition, transportation projects are typically smaller-sized and produce a lower amount of GHG emission reductions relative to most energy and forestry/land use projects. Meanwhile, the cost of ensuring uniform reporting and monitoring of all vehicles in a transportation project may be higher than normal because project developers often may need to collect data from individual vehicle owners and operators.

In addition, the average cost of qualifying a project for acceptance under a market-based program works against smaller-sized projects. USIJI estimated that the average cost of project development and approval under the USIJI reached $100,000 during the first few years of the AIJ Pilot Phase.[51,52] The World Bank's Prototype Carbon Fund (PCF) has set aside $145 million for purchasing GHG reductions. The rules for qualifying a project under the PCF are very stringent to ensure that the purchased emission reductions will qualify under any future crediting program, including the proposed JI and CDM of the Kyoto Protocol. Based on the preliminary experience with evaluating projects (mostly large-scale power plant projects), members of the PCF estimate that the cost of developing, approving and verifying a project under the CDM and JI would range between $200,000 and $400,000.[53] These high average costs may discourage development of smaller-sized projects, unless standardized emission baselines and other procedures for streamlining the project development and approval process are implemented.

Altogether, the following steps should be undertaken to encourage development of projects in the transportation sector and provide support to project developers interested in gaining recognition for their GHG mitigation activities:

1) An increase in research detailing advantages or disadvantages of using tailpipe emissions data alone instead of estimating emission reductions from the entire fuel cycle;
2) Development of standardized monitoring and verification protocols for projects using dispersed technologies, including transportation projects where vehicles are not stored, parked, and/or serviced in the same location;
3) Provision of training and/or capacity building on how to create GHG emission reduction projects using transportation technologies. This would reduce transaction costs and familiarize project developers and other entities with the potential for achieving GHG emission reductions in the transportation sector; and
4) An examination of data availability and institutional capacity needs of potential project host countries for estimating GHG emission benefits of transportation projects and developing both project-specific and multi-project emission baselines.

[51] Kenneth M. Chomitz, "Baselines for Greenhouse Gas Reductions: Problems, Precedents, Solutions," Draft Paper. World Bank, Washington D.C., July 1998.
[52] Tim Hargrave, *et al*, "Options for Simplifying Baseline Setting for Joint Implementation and Clean Development Mechanism Projects." Center for Clean Air Policy, Washington, D.C., November 1998.
[53] World Bank, Prototype Carbon Fund (PCF*)*, PCF Fund Management Team presentation at SBSTA 13, Lyon, France, September 2000. http://www.prototypecarbonfund.org. It should be noted that the PCF is applying very strict application and project development criteria to ensure that the projects approved today will be able to receive credit under any JI or CDM regime. Projects have to go through 28 stages as part of the project approval process.

4. Case Study: Compressed Natural Gas Taxis

4.1 Introduction

In the previous chapter, some of the major issues related to the quantification of NGV-related GHG benefits were highlighted. In this chapter, we take this discussion one step further and present a project case study in order to familiarize the reader with the specific issues that should be considered during the quantification of GHG emission benefits. The case study is based on a hypothetical project that involves the deployment of 75 compressed natural gas taxis to replace 75 aging gasoline-fueled taxis.[54]

The case study focuses on the process of developing the emission baseline and estimating net GHG emission benefits of the project. To make the project more realistic, other criteria for project development under the AIJ Pilot Phase, JI, and the CDM are also briefly discussed. The case study is intended to provide guidance on how to develop an emission baseline for a single GHG reduction project and does not discuss methodologies for developing standardized or multi-project baselines for the transportation sector.

It should be stressed that the framework for developing market-based GHG reduction projects is still emerging. The specific requirements for project and emission baseline development may change as new mechanisms for controlling emissions are proposed. However, this case study should still be useful for providing overall guidance on how to estimate and document the potential emission benefits of a NGV project.

In the following subsections we will provide a brief summary of the project case study, outline the overall criteria for developing a GHG reduction project under the UNFCCC, develop the project based on these criteria, and estimate the emission baseline and net project benefits.

4.2 Project Background

This case study is based on a hypothetical project in a country called the Clean Cities Republic. Although the Clean Cities Republic is a developing country, it does not represent any country or region in particular. It should be emphasized that the numbers used for this case study are invented as well. The data provided for estimating the emission baseline have been developed for illustrating how to quantify potential emission benefits, not as an indicator of the specific emissions potential of a CNG taxi project. NGV project developers should obtain their own GHG emission data for both the conventional vehicles to be replaced and the new NGVs.

The Republic of Clean Cities is a country with a population of 45 million people. Gross domestic product (GDP) is US$190 million per year, with an annual growth rate of 5 to 6 percent over the last 10 years. As a result of this economic expansion, the country is experiencing an energy demand growth of 7 percent per year, with the transportation sector representing the fastest growing energy sector. Currently, transportation activities account for 32 percent of energy-related CO_2 emissions, however this share is expected to grow significantly over the next few decades as the transportation sector continues to expand.

The Republic of Clean Cities is a non-Annex I country under the UNFCCC. This means that the Republic can undertake an AIJ pilot project with any country, either as an investor country or more likely

[54] Julie Doherty and Jette Findsen, "Case Study: CNG Taxis, The Republic of Clean Cities." Presentation for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies.* San Diego, CA, May 10, 2000.

as a host for an AIJ project. As a non-Annex I country, the Republic of Clean Cities does not have a binding emission reduction target under the proposed Kyoto Protocol. However, the country will be eligible for hosting project-related GHG reduction activities to be credited under the Clean Development Mechanism (CDM).

The project will be located in the capital of the Republic of Clean Cities, which is a city of 8 million people with a population growth of 5 percent per year. On average there are 7 people per motor vehicle compared to 1.3 per vehicle in the U.S. The total number of vehicles on the road is growing by 7 percent annually. The capital is experiencing serious local environmental pollution problems and is among the 20 most polluted cities in the world. The concentration of total suspended particulates (TSP) in the air is 8 times higher than the proposed World Health Organization (WHO) standards. The majority of the capital's pollution problems are caused by transportation emissions. To alleviate some of these environmental problems, the government has introduced tax incentives for switching to AFVs. A couple of years ago, a new law was passed mandating that all new cars should drive on unleaded gasoline. Currently, 40 percent of all gasoline sold in the country is leaded. The local government has introduced a car use reduction plan to curb the rapid growth of new vehicles in the capital area. Finally, a new domestic regulation was put in place this year for reductions in tailpipe emissions of urban pollutants.

The natural gas refueling infrastructure is still very limited in the capital as well as the rest of the Republic of Clean Cities. Indeed, no CNG refueling stations have yet been introduced in the capital. However, a new pipeline was recently built for transporting natural gas to the capital. The recent construction of the pipeline ensures that leakage from the system is still minimal. A portion of the natural gas supplied to the capital originates at an oil field where it was previously flared and/or vented into the atmosphere.

4.3 The Project Case Study

As part of the project, 75 dedicated CNG taxis (sedans) will be purchased to replace 75 aging gasoline taxis. To develop a supporting refueling infrastructure, one new CNG refueling station will be constructed at the site where these taxis are parked. Moreover, an extensive training course will be provided for the fleet mechanics. The lifetime of the project is estimated conservatively at 10 years. Each taxi is expected to drive an average of 80,000 miles per year. The total estimated GHG emission benefits of the project are expected to reach up to 11,776 tons of CO_2 equivalent.

The project participants include the Capital City Transportation Department, a local taxi fleet operator, and a U.S.-based NGV manufacturer. The CNG project has been approved by the Republic of Clean Cities' National Climate Change Office, which has been authorized by the Ministries of Foreign Affairs, Energy, and Environment to evaluate and certify AIJ and other international climate change projects. The National Climate Change Office, administered by the Ministry of Environment, has provided written documentation of project approval.

The project reduces CO_2 emissions by reducing the need for oil recovery, gasoline refining, and fuel transportation, which produces more CO_2 emissions than the production and transportation of natural gas. The CO_2 savings offset the increased CH_4 emissions associated with natural gas recovery, pipeline leakage, natural gas compression, and fuel combustion. N_2O emissions remain mostly unchanged and will not be included in the emission baseline.

4.4 Project Additionality

The question of additionality refers to the issue of whether or not a project would have occurred in the absence of the AIJ Pilot Phase, or any other future GHG reduction program, under which the project developer is applying for recognition. To ensure the environmental benefit of the proposed activities, projects must demonstrate that they are not part of the general emission reduction activities expected to take place as part of business-as-usual.

Although natural gas is cheaper than gasoline in the Republic of Clean Cities, the absence of a CNG refueling infrastructure has prevented, and will continue to prevent, vehicle operators from purchasing CNG vehicles. In particular, the high up-front cost of purchasing and installing a refueling station discourages the deployment of CNG vehicles in the capital. In addition, CNG vehicles have an incremental cost of around $5,000 per vehicle, adding another barrier to investment. This has led analysts to the conclusion that investment in CNG vehicles in the Republic will not take place without special incentives, legal requirements, or funding plans initiated by the government or some other funding source. As there are no such policies or funding initiatives currently under consideration by the local or national government authorities, it can be assumed that the deployment of CNG vehicles would not have happened without the prospect of obtaining future CDM credits. Therefore, it can be asserted that this NGV project is clearly additional.

4.5 Estimating the Emission Baseline

Only one transportation project has been recognized under the AIJ Pilot Phase. One project does not provide enough precedence to be used as meaningful guidance for other project developers. Instead, project investors should use the general experience gained from the AIJ Pilot Phase and the preliminary rules of other market-based mechanisms, such as the CDM and JI of the Protocol. A useful place to look for guidance on project development is the U.S. Initiative on Joint Implementation (USIJI). This program, which is described in more detail in Chapter 3 of this Resource Guide, was introduced during the AIJ Pilot Phase and applies some of the most stringent application criteria of all the national AIJ/JI offices.

According to the criteria of USIJI, the emission baseline should include *major* emission sources and GHGs from the project.[55] For this type of project proposal it may be sufficient to include information about tailpipe emissions only, instead of completing an entire life cycle analysis. However, it is possible that any future market-based program would require a more stringent analysis of potential emission reductions. As a result, it may not be sufficient to include only tailpipe emissions and CO_2 estimates in future project proposals.

Because of the many unanswered questions related to the requirements of establishing an emission baseline, this study will provide three sample baseline scenarios that range from less detailed to very comprehensive in nature. The baselines include:

1. A static baseline focusing on tailpipe emissions,
2. A dynamic emission baseline focusing on tailpipe emissions and changes to equipment over time, and
3. A dynamic baseline including full fuel cycle analysis and changes to equipment over time.

The purpose of presenting these different baseline scenarios is two-fold. One reason is to advance the discussion on some of the issues that must be resolved in order to establish clear guidelines for the

[55] *Resource Document on Project & Proposal Development under the U.S. Initiative on Joint Implementation (USIJI).* U.S. Initiative on Joint Implementation, Version 1, June 1997. Emphasis added.

documentation and approval of transportation-related projects. Another reason is to provide potential project developers with an idea of the issues that must be considered during the development of an emission baseline. Project developers can then choose between or combine the different levels of baseline scenarios depending on the purpose and requirements of the program to which the project participants will be applying for credit. Factors, which may determine the choice of baseline scenario, include:

1. The transportation technology used for the project,
2. Availability of full fuel cycle and tailpipe emissions data,
3. Individual program requirements,
4. The risk tolerance and level of accuracy desired by project developers and investors, and
5. The acceptable level of transaction costs.

In the following subsections, the three baseline scenarios will be outlined. Each version of the baseline scenarios involves four quantification steps. These include a calculation of (1) historic emissions, (2) the project reference case, (3) project-related emissions, and (4) net emission benefits of the project.

The first baseline quantification step involves the quantification of historic emissions; that is, emissions prior to the implementation of the project itself. The historic emissions should include an account of emissions at the project site for an extended period prior to the commencement of the project. The USIJI, for example, requires that the historic emissions include data for at least 12 consecutive months before the project start date.[56] These numbers are important because they provide a picture of what the actual emissions were at the project site before the start of the GHG reduction activities. If necessary, this information can then be used by project evaluators to determine whether the projected emission benefits fall within a reasonable range.

The second quantification step entails an estimation of what emissions would have been without the implementation of the project. This step is also known as the project reference case and should include data for the entire life of the project. Because the potential project emission benefits are derived by comparing project emissions to the reference case, accuracy in the development of the reference case is very important. However, estimating future emissions is a difficult process. It is almost impossible to factor in everything that may or may not happen 10 to 20 years down the road. Many different results can be achieved depending on which assumptions are used to derive the future emissions scenario. The text establishing the AIJ Pilot Phase provides little guidance on how specifically to estimate future emissions. Hence, the various national JI programs evaluating projects under the AIJ Pilot Phase have applied very different criteria for estimating the reference case.

Given the differences between the various initiatives to credit GHG reduction activities, and the uncertainty surrounding future crediting programs, developers of transportation-related projects should be careful to consult the guidelines of each current or proposed program before developing their project. They should also be careful to detail all assumptions and emission sources included in their estimates to facilitate review of the methodology used. The examples provided in the following case study are less comprehensive than what would be expected of a final project proposal and should only be used as an indicator of the types of data and quantification procedures that could be required from the different GHG reduction programs.

The third quantification step involves estimation of emissions from the project itself. The data provided should include an estimation of all relevant project emissions throughout the life of the project. During this process, project developers should be careful to define the boundary of the project and detail all the assumptions and emission sources included in the estimate.

---

[56] Ibid.

The fourth and final quantification step is very simple. It entails the calculation of the net emission benefits of the project. To derive the net benefits, the project developer must subtract the project emissions from the emissions estimated for the reference case. The difference will represent the net emission benefits of the project.

4.5.1 Emission Baselines: Version 1

The first scenario will be based on a static emission baseline. This means that the emissions are assumed to remain constant throughout the life of the project. This scenario does not take into consideration changes to vehicle emissions and equipment over time. In this case, the baseline emissions (i.e. the estimate of emissions absent the project) are assumed to be equal to the historic emissions of the gasoline vehicles prior to the project. Finally, Version 1 of the case study only includes tailpipe and refueling emissions. This is described as vehicle operation.

Step 1: Historic Emissions

The historic emissions in this baseline scenario include relevant GHG emissions (CO_2 and CH_4) for the one year prior to implementation of the project. In general, historic emissions should include data for at least 12 consecutive months prior to the project. Table 8 lists emissions of CO_2 and CH_4 of one of the taxis scheduled to be replaced by the project. The last column in the table lists emissions in terms of CO_2 equivalent (CO_2E). This means that emissions of CH_4 have been multiplied by 21 (the GWP for methane) to find the carbon dioxide equivalent global warming potential of methane. The resulting number (2.1) has then been added to the CO_2 emissions (410.0) to find the total emissions per mile for one conventional taxi (412.1 g CO_2E/mile).

Table 8. Version 1 of Case Study – Historic Emissions 12 Months Prior to the Project

	Grams/mile **Vehicle Operation of One Conventional Taxi**	
CH_4	0.1	2.1 (0.1 x 21)
CO_2	410.0	+ 410.0
Total		**412.1 g CO_2E/mile**

Emissions one year prior to project:

412.1 g CO_2E/mile x 80,000 miles x 75 cars = 2,472.6 metric tons of CO_2E

Once the total CO_2 equivalent emissions per mile of one taxi has been derived (in this case 412.1 g CO_2E/mile), this number is multiplied by the average number of miles driven by each car per year (80,000 miles) and the number of vehicles in the fleet (75 cars). The sum, which is divided by 1,000,000 to show the result in terms of metric tons, represents total historic emissions during the one year prior to the project. As indicated above, historic emissions for Version 1 of the case study are 2,472.6 metric tons of CO_2 equivalent.

Step 2: The Reference Case

The reference case represents what would have happened if the GHG reduction project were not implemented. In this case, it is assumed that the 75 old gasoline taxis, with an average age of 8 years, would have remained on the road for the next 10 years. Because Version 1 of the case study assumes that emissions of the project are static, the GHG emissions of one taxi over the next 10 years will remain the same; that is, emissions will equal the annual historic emissions of one taxi as illustrated above. Hence, the numbers in Table 9 are the same as those provided in Table 8 of this case study. The only difference between Step 1 and Step 2 is that annual emissions are multiplied by 10 to derive project emissions over the life of the project. The result is then converted into metric tons of CO_2 equivalent. As indicated below, the reference case for Version 1 of the case study is 24,726 metric tons of CO_2 equivalent.

Table 9. Version 1 of Case Study – The Reference Case

	Grams/mile **Vehicle Operation of One Conventional Taxi**	
CH_4	0.1	2.1 (0.1 x 21)
CO_2	410.0	+ 410.0
Total		**412.1 g CO_2E/mile**

Reference case – one year historic emissions multiplied by 10:

412.1 g CO_2E/mile x 80,000 miles/year x 75 cars x 10 years = 24,726 metric tons of CO_2E over the life of the project

Step 3: The Project Case

The project case represents emissions of the project itself. In this instance, the project case refers to the emissions of the 75 CNG taxis over the 10-year life of the project. Table 10 describes annual emissions of one new CNG taxi. As is expected, CH_4 emissions of the CNG taxis are higher and CO_2 emissions are lower than the respective emissions of the gasoline taxis to be replaced. Again, the last column in the table lists the emissions factor in terms of CO_2 equivalent. This means that emissions of CH_4 have been multiplied by 21 (the GWP for methane) to find the carbon dioxide equivalent global warming potential of methane. Table 10 indicates that the emissions factor of one CNG taxi is 262.6 g of CO_2 equivalent per mile driven.

Table 10. Version 1 of Case Study – The Project Case

	Grams/mile **Vehicle Operation of One CNG Taxi**	
CH_4	0.6	12.6 (0.6 x 21)
CO_2	250.0	+ 250.0
Total		**262.6 g CO_2E/mile**

Project case – emissions for one year multiplied by 10:

> 262.6 g CO_2E/mile x 80,000 miles/year x 75 cars x 10 years = 15,756 metric tons of CO_2E over the life of the project

To find emissions during the life of the project, the emissions factor of one CNG vehicle is multiplied by the average miles driven per year (80,000), the number of vehicles in the fleet (75) and the expected number of years of the project (10). After the number has been converted into metric tons, the resulting project emissions are estimated at 15,765 metric tons of CO_2 equivalent.

Step 4: Deriving Net Project Benefits

The net project emission benefits are derived by subtracting the project case from the reference case. As illustrated below, the net project benefits of Version 1 of the case study are 8,970 metric tons of CO_2 equivalent.

Reference case	-	project case	=	Net project benefits
24,726	-	15,756	=	8,970 metric tons of CO_2E

4.5.2 Emission Baselines: Version 2

The second scenario for the CNG vehicle project relies on a dynamic emission baseline. A dynamic baseline takes into account the changes that may happen to equipment, and thus emissions, as the vehicles age over time; that is, emissions of a vehicle will grow at an increasing rate every year. In this version, it will therefore no longer be sufficient to use the historic emissions for estimating the reference case. Rather, the data for estimating the reference case and project emissions will have to be based on an evaluation of how the aging process influences the two different vehicle types. The numbers used in this case study are hypothetical and are not based on any particular studies on the relationship between emissions and vehicle age. Similar to Version 1 of this case study, we only include tailpipe and refueling emissions in Version 2. This is described as vehicle operations.

Step 1: Historic Emissions

The historic emissions in this baseline scenario include CO_2 and CH_4 emissions one year prior to the implementation of the project. Table 11 lists emissions of CO_2 and CH_4 of one of the taxis scheduled to be replaced by the project. These numbers are similar to the data provided for Version 1, Step 1 of this case study. The last column in the table lists emissions in terms of CO_2 equivalent. This means that emissions of CH_4 have been multiplied by 21 (the GWP for methane) to find the carbon dioxide equivalent global warming potential of methane. The total historic emissions factor of one conventional taxi is 412.1 g CO_2 equivalent per mile.

Table 11. Version 2 of Case Study – Historic Emissions 12 Months Prior to the Project

	Grams/mile Vehicle Operation of One Conventional Taxi	
CH_4	0.1	2.1 (0.1 x 21)
CO_2	410.0	+ 410.0
Total		**412.1 g CO_2E/mile**

Emissions one year prior to project:

412.1 g CO_2E/mile x 80,000 miles x 75 cars = 2,472.6 metric tons of CO_2E

Once the total CO_2 equivalent emissions per mile of one taxi has been derived, this number is multiplied by the average number of miles driven per year (80,000 miles) and the number of vehicles in the fleet (75 cars). The sum, which is divided by 1,000,000 to show the result in terms of metric tons, represents total historic emissions during the one year prior to the project. As indicated above, historic emissions for Version 2 of the case study are 2,472.6 metric tons of CO_2 equivalent.

Step 2: The Reference Case

The reference case represents what would have happened if the GHG reduction project were not implemented. As in Version 1 of this case study, it is assumed that the 75 old gasoline taxis, with an average age of 8 years, would have remained on the road for the next 10 years. However, in this second emission baseline scenario, it is assumed that the emissions of the old vehicles would have increased at an increasing rate due to equipment failure and aging of the gasoline taxis. Moreover, it is assumed that 10 percent of the old vehicles would have been replaced by new gasoline vehicles due to age or accidents, thereby slowing emissions growth. Because of these annual changes, the emissions of each vehicle are expected to change, as seen in Table 12.

Table 12. Version 2 of Case Study – The Reference Case

	Vehicle Operation (grams/mile)										**Total CO_2E for Project (mt)**
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH_4(in CO_2E*)	2.10	2.10	2.10	2.31	2.31	2.52	2.52	2.73	2.94	3.15	
CO_2	410.00	412.00	414.00	417.00	420.00	423.00	425.00	429.00	434.00	438.00	
Total g CO_2E/mile	412.10	414.10	416.10	419.31	422.31	425.52	427.52	431.73	436.94	441.15	
Total mt CO_2E/ year**	2472.60	2484.6	2496.60	2515.86	2533.86	2553.12	2565.12	2590.38	2621.64	2646.9	**25,480.68**

* CO_2E (CO_2 Equivalent) = CH_4 x 21

** Total mt CO_2E/year = (grams CO_2E/mile * 80,000 miles/car/year * 75 cars) / (1,000,000 grams/metric ton)

The first row in the table lists the estimated CH_4 emission factor (grams/mile) for one taxi expressed in terms of CO_2 equivalent. The second row lists the CO_2 emission factor during the life of the project. These emission factors are summed and listed in row three of the table. Finally, in the bottom row, we have multiplied the emission factor of one taxi (e.g.: 412.10 g CO_2E/mile for 2001) with the average miles driven annually of one car (80,000). The result is then multiplied by the number of vehicles in the fleet (75) to find the emissions of the entire project for that year. To convert the total project emissions each year into metric tons, the number is then divided by 1,000,000. As shown in the last column of the table, the total emissions of the reference case (the sum of the annual emissions) are estimated to reach 25,480.68 metric tons of CO_2 equivalent during the 10-year life of the project.

Step 3: The Project Case

The project case represents emissions of the project itself. As in Version 1 of this case study, the project case refers to the emissions of the 75 CNG taxis over the 10-year life of the project. However, in this case it is assumed that emissions will increase at an accelerating rate due to equipment failure and aging. In addition we assume that 4 percent of the vehicles would have been replaced by new NGVs due to age or accidents, slowing emissions growth. Because of these changes, the emissions of each vehicle are expected to change each year, as seen in Table 13. The last row in Table 13 lists annual emissions in terms of metric tons of CO_2 equivalent.

Table 13. Version 2 of Case Study – The Project Case

	Vehicle Operation (grams/mile)										Total g CO_2E for Project (mt)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH_4(in CO_2E*)	2.6	2.6	2.81	2.81	2.81	3.02	3.02	3.23	3.44	3.65	
CO_2	250.0	250.0	251.00	251.00	252.00	253.00	254.00	256.00	258.00	261.00	
Total g CO_2E*/mile	252.6	252.6	253.81	253.81	254.81	256.02	257.02	259.23	261.44	264.65	
Total mt CO_2E/ year**	1515.6	1515.6	1522.86	1522.86	1528.86	1536.12	1542.12	1555.38	1568.64	1587.9	**15,395.94**

* CO_2E (or CO_2 Equivalent) = CH_4 x 21

** Total mt CO_2E/year = (grams CO_2E/mile * 80,000 miles/car/year * 75 cars) / (1,000,000 grams/metric tons)

The first row in the table lists the estimated CH_4 emission factor (grams/mile) for one taxi expressed in terms of CO_2 equivalent. The second row lists the CO_2 emission factor. These emission factors are summed and listed in row three of the table. Finally, in the bottom row, we have multiplied the emission factor of one taxi (e.g.: 1515.6 g CO_2E for 2001) with the average miles driven (80,000 miles/year) of one car. The result is then multiplied by the number of vehicles in the fleet (75) to find the emissions of the entire project for each year. To convert the total project emissions each year into metric tons, the number is divided by 1,000,000. As shown in the last column of the table, the total emissions during the life of the project are estimated to be 15,395.94 metric tons of CO_2 equivalent.

Step 4: Deriving Net Project Benefits

The net project emission benefits are derived by subtracting the project case from the reference case. As illustrated below, the net project benefits of Version 2 of the case study are 10,085 metric tons of CO_2 equivalent.

Reference case	-	project case	=	Net project benefits
25,481	-	15,396	=	10,085 metric tons of CO_2E

4.5.3 Emission Baselines: Version 3

The third version of the emission baseline for the CNG vehicle project also relies on a dynamic emission baseline. The baseline incorporates changes due to age and equipment failure over time. However, unlike Versions 1 and 2 of this case study, this emission baseline includes data for the entire fuel cycle of the CNG and gasoline vehicles included in the study. Hence, this baseline is much more detailed than the two previous versions. Emissions data are presented for three stages of the fuel cycle: feedstock, fuel and vehicle operation.[57]

Step 1: Historic Emissions

The historic emissions in this baseline scenario include relevant GHG emissions for the entire fuel cycle and are based on data collected as of one year prior to the implementation of the project. Table 14 lists emissions of CO_2 and CH_4 of one of the taxis scheduled to be replaced by the project. The last column in the table lists emissions in terms of CO_2 equivalent. This means that emissions of CH_4 have been multiplied by 21 (the GWP for methane) to find the carbon dioxide equivalent global warming potential of methane. The total historic emissions of one conventional taxi are 335.58 g CO_2 equivalent per mile.

Table 14. Version 3 of Case Study – Historic Emissions 12 Months Prior to the Project

	Grams/mile **Vehicle Operation of One Conventional Taxi**			
	Feedstock	Fuel	Vehicle Operation	Total
CH_4	0.80	0.08	0.10	20.58 (0.98x21)
CO_2	30	35	250	+315
Total				**335.58 g CO_2E/mile**

Emissions one year prior to project:

335.58 g CO_2E/mile x 80,000 miles x 75 cars = 2,013.48 metric tons of CO_2E

Once the CO_2 equivalent emission factor of one taxi has been derived (335.58 g CO_2 equivalent per mile), this number is multiplied by the average number of miles driven per year (80,000 miles) and the number of vehicles in the fleet (75 cars). The sum, which is divided by 1,000,000 to show the result in terms of metric tons, represents total historic emissions during the one year prior to the project. As indicated above, historic emissions for Version 3 of the case study are 2,013.48 metric tons of CO_2 equivalent per year.

[57] The feedstock-related stage includes feedstock recovery, transportation, and storage. The fuel-related stage includes fuel production, transportation, storage, and distribution. The vehicle operation stage includes vehicle refueling, tailpipe and operations.

Step 2: The Reference Case

The reference case represents what would have happened if the GHG reduction project were not implemented. As in the previous versions of this case study, it is assumed that the 75 old gasoline taxis, with an average age of 8 years, would have remained on the road for the next 10 years. Moreover, it is assumed that the emissions of the old vehicles would have increased at a growing rate due to equipment failure and aging of the gasoline taxis. It is also assumed that 10 percent of the vehicles would have been replaced by new gasoline vehicles due to age or accidents, slowing emissions growth. Finally, data is collected for the entire fuel cycle of the project (Tables 15.A-C).[58]

Table 15.A Version 3 of Case Study – The Reference Case (Feedstock)

	Feedstock (grams/mile)										Total CO_2E (mt)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH_4(in CO_2E*)	10.50	10.50	10.71	10.71	10.92	10.92	11.13	11.34	11.55	11.76	
CO_2	30.00	30.00	31.00	31.00	32.00	33.00	34.00	36.00	38.00	41.00	
Total g CO_2E/mile	40.50	40.50	41.71	41.71	42.92	43.92	45.13	47.34	49.55	52.76	
Total mt CO_2E/year**	243.00	243.00	250.26	250.26	257.52	263.52	270.78	284.04	297.30	316.56	**2,676.24**

Table 15.B Version 3 of Case Study – The Reference Case (Fuel)

	Fuel (grams/mile)										Total CO_2E (mt)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH_4(in CO_2E*)	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	
CO_2	75.00	75.00	76.00	76.00	77.00	77.00	78.00	79.00	80.00	81.00	
Total g CO_2E/ mile*	77.73	77.73	78.73	78.73	79.73	79.73	80.73	81.73	82.73	83.73	
Total mt CO_2E/ year**	466.38	466.38	472.38	472.38	478.38	478.38	484.38	490.38	496.38	502.38	**4,807.8**

Table 15.C Version 3 of Case Study – The Reference Case (Vehicle Operation)

	Vehicle Operation (grams/mile)										Total CO_2E (mt)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH_4(in CO_2E*)	2.10	2.10	2.10	2.31	2.31	2.52	2.52	2.73	2.94	3.15	
CO_2	410.00	412.00	414.00	417.00	420.00	423.00	425.00	429.00	434.00	438.00	
Total g CO_2E/mile*	412.10	414.10	416.10	419.31	422.31	425.52	427.52	431.73	436.94	441.15	
Total mt CO_2E/year**	2472.60	2484.60	2496.6	2515.86	2533.86	2553.12	2565.12	2590.38	2621.64	2646.90	**25,480.68**

* CO_2E (CO_2 Equivalent) = CH_4 x 21
** Total mt CO_2E/year = (grams CO_2E/mile * 80,000 miles/car/year * 75 cars) / (1,000,000 grams/metric ton)

[58] Similar to the GREET model we have divided the full fuel cycle intro three stages. The feedstock-related stage includes feedstock recovery, transportation and storage. The fuel-related stage includes fuel production, transportation, storage and distribution. The vehicle operation stage includes vehicle refueling, vehicle operations, and fuel combustion (also known as tailpipe emissions).

The first row in Tables 15 A-C lists the estimated CH_4 emission factor (grams/mile) for one taxi expressed in terms of CO_2 equivalent. The second row lists the CO_2 emission factor. These emission factors are summed and listed in row three of the tables. In the bottom row, we have multiplied the emission factor of one taxi with the average miles driven annually (80,000) of each car. The result is then multiplied by the number of vehicles in the fleet (75) to find the total emissions for each year. To convert the total emissions per year into metric tons, the number is then divided by 1,000,000.

Finally, emissions from the entire fuel cycle (feedstock = 2,676 mt CO_2E; fuel = 4,808 mt CO_2E; vehicle operation = 25,481 mt CO_2E) are added together. The resulting emissions for the 10-year reference case are 32,965 metric tons of CO_2 equivalent.

Step 3: The Project Case

As in the previous versions of this case study, the project case refers to the emissions of the 75 CNG taxis over the 10-year life of the project. It is assumed that emissions will increase at an accelerating rate due to equipment failure and aging. In addition, we assume that 4 percent of the vehicles would have been replaced by new NGVs due to age or accidents, slowing emissions growth. However, in this version, data for the entire project fuel cycle is included in the analysis.

Table 16.A Version 3 of Case Study – The Project Case (Feedstock)

	Feedstock (grams/mile)										Total CO_2E (mt)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH_4(in CO_2E*)	16.80	16.80	16.80	17.01	17.01	17.01	17.22	17.22	17.43	17.43	
CO_2	28.00	28.00	29.00	29.00	30.00	30.00	31.00	32.00	33.00	34.00	
Total g CO_2E/mile	44.80	44.80	45.80	46.01	47.01	47.01	48.22	49.22	50.43	51.43	
Total mt CO_2E/year**	268.80	268.80	274.80	276.06	282.06	282.06	289.32	295.32	302.58	308.58	**2848.38**

Table 16.B Version 3 of Case Study – The Project Case (Fuel)

	Fuel (grams/mile)										Total CO_2E (mt)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH_4(in CO_2E*)	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	
CO_2	35.00	35.00	36.00	36.00	37.00	37.00	38.00	39.00	40.00	41.00	
Total g CO_2E/mile	36.68	36.68	37.68	37.68	38.68	38.68	39.68	40.68	41.68	42.68	
Total mt CO_2E/year**	220.08	220.08	226.08	226.08	232.08	232.08	238.08	244.08	250.08	256.08	**2344.80**

Table 16.C Version 3 of Case Study – The Project Case (Vehicle Operation)

	Vehicle Operation (grams/mile)										Total CO_2E (mt)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
CH_4(in CO_2E*)	12.60	12.60	12.81	12.81	12.81	13.02	13.02	13.23	13.44	13.65	
CO_2	250.00	250.00	251.00	251.00	252.00	253.00	254.00	256.00	258.00	261.00	
Total g CO_2E/mile	262.6	262.6	263.81	263.81	264.81	266.02	267.02	269.23	271.44	274.65	
Total mt CO_2E/year**	1575.60	1575.60	1582.86	1582.86	1588.86	1596.12	1602.12	1615.38	1628.64	1647.90	**15,995.94**

* CO_2E (CO_2 Equivalent) = CH_4 x 21

** Total mt CO_2E/year = (grams CO_2E/mile * 80,000 miles/car/year * 75 cars) / (1,000,000 grams/metric ton)

The first row in Tables 15 A-C lists the estimated CH_4 emission factor (grams/mile) for one taxi expressed in terms of CO_2 equivalent. The second row lists the CO_2 emission factor each year over the life of the project. These emission factors are summed and listed in row three of the tables. In the bottom row, we have multiplied the emission factor of one taxi with the average miles driven annually (80,000) per car. The result is then multiplied by the number of vehicles in the fleet (75) to find the emissions of the entire project for each year. To convert the total project emissions per year into metric tons, the number is then divided by 1,000,000.

Finally, the emissions from the entire fuel cycle (feedstock = 2,848 mt CO_2E; fuel = 2,345 mt CO_2E; vehicle operation = 15,996 mt CO_2E) are added together. The resulting emissions for the 10-year life of the project are estimated to reach 21,189 metric tons of CO_2 equivalent.

Step 4: Deriving Net Project Benefits

The net project emission benefits are derived by subtracting the project case from the reference case. As illustrated below, the net project benefits of Version 3 of the case study are 11,776 metric tons of CO_2 equivalent.

Reference case	-	project case	=	Net project benefits
32,965	-	21,189	=	11,776 metric tons of CO_2E

5. The Future of Alternative Fuel Vehicles

5.1 Introduction

Although this manual focuses on the creation of GHG emission reduction projects using NGVs, many of the basic principles discussed for estimating baselines and additionality and documenting GHG emission reductions also apply to other transportation-related projects. While NGVs continue to be deployed at an increasing rate and offer substantial opportunities for reducing emissions in the transportation sector, there are also other technologies with the potential to meet medium- to long-term needs for transportation-related emission reductions.

The commercial deployment of NGVs continues to increase worldwide as issues including availability of re-fueling infrastructure, reduction of re-fueling time, and vehicle range, cost, and performance are resolved. As NGV use grows, governments and automobile manufacturers are also researching new types of AFV technologies and ways to improve existing technology. Other advanced technologies with the potential for use as GHG emission reduction projects include electric and hybrid electric vehicles, hydrogen fuel cell technologies, and gas-to-liquids, also known as "clean diesel." Though numerous other applications of AFVs are available, the above-listed technologies are the focus of this chapter due to their medium- to long-term potential to be used in addition to or as a replacement for NGVs. As more of these AFVs are manufactured, their cost is expected to drop due to economies of scale and resolution of many of the technological barriers.

5.2 Electric Vehicles

Electric vehicles (EVs) operate much like traditionally fueled vehicles, except that they run on an electric motor instead of a combustion engine, and batteries instead of a fuel tank. Electricity is unique among the alternative fuels in that mechanical power is derived directly from it, whereas conventional fuels release stored chemical energy through combustion to provide motive power. Most often the electricity used to power EVs is provided by batteries. Researchers are also exploring the use of fuel cells to convert chemical energy to electricity, rather than relying on batteries for electricity storage (see Section 5.3 Hydrogen).

Since EVs can be recharged at home and/or at a fleet parking facility, they generally require no additional infrastructure, such as the building and/or modification of existing refueling stations. In addition, EVs are typically refueled during low-demand hours, so refueling is not limited by power supply. Assuming that vehicle manufacturers are able to bring down cost and increase vehicle range and that there are improvements in battery technology (see Section on Battery Types below), electric vehicles have the potential to become commercially deployed and serve as GHG emission reduction projects.

There are indications that certain applications of EVs may provide GHG emission reduction benefits of between 55 percent and 99.9 percent (CO_2 equivalent) depending on the energy source used for electricity generation.[59] Thus, provided that the source of electricity for refueling EVs is less carbon intensive than the full fuel-cycle CO_2 emissions from other transportation technologies, EVs have the potential to reduce the emissions and carbon intensity of the world's transportation sector.

[59] Electric Vehicle Association of Canada, "Full Fuel Cycle Emission Reductions Through the Replacement of

5.2.1 Hybrid-Electric Technology

Hybrid electric vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle, resulting in twice the fuel economy of conventional vehicles.[60] This combination offers the extended range and rapid refueling that consumers expect from a conventional vehicle, and a significant portion of the energy and environmental benefits of an electric vehicle. The practical benefits of HEVs include improved fuel economy and lower emissions compared to conventional vehicles. The inherent flexibility of HEVs allows them to be used in a wide range of applications, from personal transportation to commercial hauling.

HEVs have the potential to significantly reduce GHGs due to factors including:

- Increased fuel efficiency (hybrids consume significantly less fuel than vehicles powered only by conventional fuels); and
- A reduction in dependency on fossil fuels because they can run on alternative fuels.

One of the most common forms of hybrid-electric technology is a heavy-duty application that combines an electric drivetrain with a diesel engine, which powers an alternator or generator to produce electrical power for heavy-duty application. This application is currently used by New York City Transit Authority and is being considered by other transit agencies in the United States. Decoupling the engine from the drivetrain allows it to be operated independently of vehicle speed. At a steady-state operating speed, a hybrid bus might be <u>less</u> fuel-efficient than the same bus using a conventional drivetrain. However, the real world driving conditions of the typical transit bus involves constant starts and stops. With a conventional drivetrain, the engine must be sized to provide sufficient power to accelerate the bus while operating all the needed accessories. A hybrid bus reduces the maximum power demand on the engine by recapturing braking energy and using it to help accelerate the bus from rest. This reduces the peak power requirement of the engine, allowing it to be smaller. By decoupling the engine from the drivetrain, further gains are possible by operating the engine only at its most efficient speeds and loads. Emissions are reduced, primarily as a function of reduced fuel consumption.

A current major concern with hybrid-electric buses is premature battery failure due to uneven charging. A partial remedy is an added maintenance step requiring charging of the batteries overnight or for an entire day to equalize their initial state of charge and operating voltage. At least once a month, this is recommended for hybrid buses in the field. Unless premature battery failure can be avoided, the cost of operating hybrid buses will be very high.

Hybrid buses are currently about 50 percent more expensive than conventional buses. Contributions to this increased expense include:

- an electronic control system;
- a battery pack for energy storage;
- an electric drive motor; and
- recouping of R&D investments.

Hybrid busses are more expensive despite their smaller engines and simpler transmission systems. Also, because diesel engine emission standards are specified in terms of power output, any cost to comply with new engine emissions standards will apply equally to the engines used in hybrid and conventional buses.

[60] DOE Clean Cities Website, “What is an HEV?” http://www.ott.doe.gov/hev/what.html.

5.2.2 Battery Types

A large number of battery types are being tested for use in EVs. Some of the technologies under evaluation include lead-acid, nickel cadmium, nickel iron, nickel zinc, nickel metal hydride, sodium nickel chloride, zinc bromine, sodium sulfur, lithium, zinc air, and aluminum air.

In 1999, 1,277 battery light-duty vehicles were sold or leased in the United States. As of November 2000, an additional 476 battery light-duty vehicles were sold or leased in the United States. In both years, the Ford Ranger EV accounted for the majority of vehicles sold.

5.3 Hydrogen

The lightest potential alternative fuel is hydrogen gas (H_2). Hydrogen is in a gaseous state at atmospheric pressure and ambient temperatures. Fuel hydrogen is not pure hydrogen gas, but rather contains small amounts of oxygen and other materials. H_2 is being explored for use in combustion engines and fuel-cell electric vehicles, although it presents greater transportation and storage hurdles than exist for the liquid fuels.[61] Storage systems being developed include systems designed for compressed hydrogen, liquid hydrogen, or a chemical bonding process between hydrogen and a storage material (for example, metal hydrides). Hydrogen is typically transported in canisters and tanker trucks. While no hydrogen-based distribution and refueling system is in place for the transportation sector, the ability to create the fuel from a variety of sources and its clean-burning properties make it a desirable alternative to conventional fuels.[62]

Two methods are generally used to produce hydrogen: (1) electrolysis and (2) synthesis gas production from steam reforming or partial oxidation. Electrolysis uses electrical energy to split water molecules into hydrogen and oxygen. The electrical energy can come from any electricity production source including renewable fuels. DOE has concluded that electrolysis is unlikely to become the predominant method for large quantities of hydrogen. The predominant method for producing synthesis gas today is steam-reforming of natural gas, although other hydrocarbons can be used as feedstocks. For example, biomass and coal can be gasified and used in a steam-reforming process to create hydrogen.

5.3.1 Hydrogen Fuel Cells

Hydrogen fuel cells can be used as power generating systems for electric vehicles. They differ from battery-driven vehicles in that they store fuel, not energy. A hydrogen fuel cell works by converting the chemical energy of hydrogen and combining it with oxygen to produce electricity, heat, and water. The hydrogen is stored in tanks on board the vehicle, either as a liquid or as a gas. Fuel cell vehicles are still in the developmental stage, but with advances in technology, they may become viable.

5.4 Clean Diesel

Clean diesel typically means diesel-fuel that is ultra-low in sulfur and nitrogen. Over the last few years, clean diesel has received much attention because it allows new power-train/fuel systems, such as fuel cells and ultra-clean diesel engines, to become reality. These new fuel systems will be necessary to meet the increasingly stringent clean air standards in the U.S. For example, the Environmental Protection Agency (EPA) recently introduced a rule requiring new pollution control devices to be effective on trucks

[61] Please note that researchers are investigating on-board reforming of liquid hydrocarbon or methanol for producing hydrogen for fuel cell-driven vehicles. This would avoid hydrogen storage problems.
[62] While pipeline transportation is generally the most economic means of transporting gaseous fuels, a pipeline system for hydrogen is currently not in place.

and buses between 2007 and 2010 and mandating the sulfur content of highway diesel fuel to be reduced from its current level of 500 parts per million to 15 parts per million by 2006.[63]

New compression ignition (CI) engines are under development to meet the increasing dual challenges of greater fuel efficiency and reduced emissions of environmental pollutants. In particular, low-emission diesel engines are attractive because of their inherent 40% increase in fuel efficiency compared to gasoline engines. However, diesel engines are beginning to reach the limit of their performance envelope without substantial fuel improvements. The catalytic converters required to reduce oxides of nitrogen (NOX) emissions can not be used at present because the high sulfur levels (300 ppm) in the currently available fuels rapidly poison the catalyst of these anti-pollution devices. Ultra-clean diesel fuels could offer a way for these new vehicles to meet the more stringent emission standards without compromising safety, performance, or affordability.

5.4.1 Gas-to-Liquids (GTL) Synthetic Fuel

The most promising method for producing clean diesel is the gas-to-liquids (GTL) synthetic fuel produced through the Fischer-Tropsch (FT) process. Synthetic fuel in the diesel range is made from natural gas using any of several FT processes. Unlike liquefied natural gas processing where natural gas is cooled to form a liquid, GTL technologies chemically change the natural gas molecules, breaking them apart, and re-combining them with oxygen to form a mixture called synthesis gas. In turn, synthesis gas can be chemically converted into different types of hydrocarbon products like clean-burning transportation fuels (clean diesel) or a variety of high-value chemicals. This conversion into liquid hydrocarbons (FT liquids) takes place on a Fischer-Tropsch catalyst. The synthetic fuel created through this process contains no detectable sulfur, aromatics, olefins, or alcohols. By eliminating these undesirable species, diesels can be made to operate as cleanly as gasoline or CNG engines, without penalizing efficiency.

One of the potential uses for GTL technology and clean diesel is as a replacement fuel for conventional diesel or as a blending agent with conventional fuels to help meet more stringent environmental regulations. Diesel with an ultra-low sulfur content is needed for emission control devices to reduce emissions of NOx and particulates effectively. Sulfur is a major impediment to implementation of the emission control technology needed in diesel engines and can even cause increased particulate emissions when used with advanced catalytic particulate control devices designed to reduce emissions.[64]

Another use for clean diesel is as a fuel source for fuel cells. Both industry and government researchers have focused on conventional gasoline and diesel as fuel cell fuels because they can be delivered using the present fuel distribution system and have relatively high hydrogen carrying capacity. Like the diesel engine manufacturers, fuel cell fuel technology providers also prefer fuel with not detectable sulfur. As a result, clean diesel provides a useful fuel alternative that will help advance the development and utilization of fuel cells.

Compared to the obvious benefits on local air pollutants, the greenhouse gas emissions benefits of GTL technology are not as evident. The driving force behind GTL as a transportation fuel is that emissions of sulfur, NO_x, and particulate matter are significantly reduced compared to conventional transportation fuels. In terms of greenhouse gas emissions, there is no difference between conventional and new diesel –

---

[63] "EPA Dramatically Reduces Pollution From Heavy-Duty Trucks and Buses; Cuts Sulfur Levels in Diesel Fuel" Press Release, U.S. Environmental Protection Agency (EPA). Washington, DC. December 21, 2000. http://www.epa.gov.
[64] Wendy Clark, *et al*, "Overview of Diesel Emission Control—Sulfur Effects Program," SAE Paper 2000-01-1876 Presented at the CEC/SAE International Spring Meeting. Paris, France, June 19-22, 2000.

except in cases where the use of clean diesel allows for the use of a more fuel-efficient engine. However, there is a secondary effect to GTL that directly contributes to the reduction of greenhouse gas emissions; that is, GTL provides a use for natural gas that otherwise would have been flared. In this context, an argument could be made that a project utilizing GTL technology presents an alternative to natural gas flaring which results in greenhouse gas emission reductions.

There are approximately 12 GTL projects worldwide only two of which (both in South Africa) are currently operational. The remaining projects are considered potential and located in the United States, Venezuela, the United Kingdom, Nigeria, Norway, Qatar, Bangladesh, and Malaysia.[65] Despite the small number of projects, capital costs for a GTL project are becoming competitive with those associated with refining processes for conventional transportation fuel technologies. The U.S. Department of Energy estimates that the costs of the chemical conversion process could be reduced by 25 percent if a one-step process can be developed to separate oxygen from the air and combine it with natural gas to form synthesis gas. It would bring gas-to-liquid technology into the $18 to $20 per barrel range, which is competitive with crude oil.[66]

GTL also has unique economic advantages over other alternative fuel technologies on the distribution and end-use sides. First, GTL technologies yield products that can be used directly as fuels or feedstocks or they can be blended with crude oil products to help comply with more stringent environmental requirements. Second, use of GTL fuels would not necessitate the rebuilding of vehicle fleets and distribution systems. GTL fuels could be delivered through existing infrastructures and existing vehicles would not necessarily need extensive modifications.[67] Other alternative fuels like CNG require new distribution systems, fueling stations, vehicle modifications, and cannot be blended with other crude oil products.

[65] Mark A. Agee, President and CEO, Syntroleum Corporation, Tulsa, OK "Fuels for the Future," Paper presentation at the *Energy Frontiers International Conference, Gas Conversion: Projects, Technologies, & Strategies.* San Francisco, CA October 20-22, 1999, http://www.syntroleum.com/pdfs/sf_1099.pdf.

[66] *DOE Fossil Energy Techline*, "University of Alaska-Fairbanks to Lead University, Industry Team, in Department of Energy Project to Develop 'Gas-to-Liquids' Technology," April 16, 1999, http://www.fe.doe.gov/techline/tl_akgastoliq.html.

[67] Mark A. Agee, President and CEO, Syntroleum Corporation, Tulsa, OK, "Economic Gas To Liquids Technologies – A New Paradigm for the Energy Industry," Paper presentation at *Montreux Energy Roundtable VIII*. Montreux, Switzerland, May 12-14, 1997, http://www.syntroleum.com/pdfs/montreux597.pdf and "GTL vs. Low Oil Prices – The Insulating Factors." Paper Presentation at *Monetizing Stranded Gas Reserves '98 Conference.* San Francisco, CA, December 14-16, 1998, http://www.syntroleum.com/pdfs/sf_1298.pdf.

Appendix 1. A Comparison of the CAAA90 Clean Fuel Fleet Program and the Provisions of EPAct That May Have an Impact on the NGV Project Developer

TOPIC	Clean Air Act Amendments of 1990	Energy Policy Act of 1992
Persons Affected	Public or private fleet owners or operators with 10 or more vehicles centrally fueled or capable of being centrally fueled 100% of the time.	• "Persons" who own, operate, lease, or control at least 50vehicles in the United States (centrally fueled or capable of being centrally fueled), primarily operated in a Consolidated Metropolitan Statistical Area(CMSA) with a 1980 population of 250,000 or more. • For state government fleets, "persons' affected bay be the entire state government fleet, or all the individual state agency fleets, aggregated in groups of two or more agencies. • For alternative fuel providers, "persons" affected refers to fuel providers: (1) whose "principal business" is producing, storing, refining, processing, transporting, distributing, importing or selling (at wholesale or retail) any alternative fuel (other than electricity); or (2) whose "principal business" is generating, transmitting, importing, or selling (at wholesale or retail) electricity; or (3) if those fuel providers produce, import, or produce and import (in combination) an average of 50,000barrels per day or more of petroleum and 30% or more of their gross annual revenues are derived from procuring alternative fuels.
Areas Affected	Metropolitan areas with 1980 populations of 250,000 or more and designated by EPA as being in serious, severe, or extreme non-attainment of either ambient ozone or carbon monoxide (CO) standards.	More than 120 cities with 1980 populations of 250,000 or more.
Fleet Definition	Ten or more heavy-duty vehicles (HDVs) or light-duty passenger cars (LDVs)or trucks (LDTs) operated in the affected area. • LDVs/LDTs: <8,500 lbs gross vehicle weight (GVW). • HDVs: 8,500-26,000 lbs GVW.	Fleets of 20 or more LDVs or LDTs less than 8,500 lbs. GVW capable of being centrally fueled that are owned, operated, leased, or controlled by a governmental entity or by another person who controls 50 or more such vehicles.
Important Dates	Requirements take being in 1998.	• Federal fleet requirements began in 1993. • State and fuel provider requirements begin in 1997. • Municipal/private fleets by 2002.
Purchase Requirements	Covered fleets need to buy clean fuel vehicles (CFVs) as a percentage of new vehicle purchases.	Beginning in 1996, covered fleets need to buy alternative fuel vehicles as a percentage of new vehicle purchases.
Buses	Urban Bus Standards: • For the 1994 and 1995 model years, urban bus engines must meet a 0.07grams per brake horsepower hour (g/bhp-hr) particulate matter (PM) emissions standard. For 1996 and later model years, the PM standard is 0.05 g/bhp-hr. • EPA must perform annual testing of a representative sample of 1994 and later model year urban buses. If EPA determines that urban buses are not complying with the PM standards, the CAA requires the use of "low-polluting fuels" (methanol, ethanol, propane, natural gas, or any comparably low-polluting fuel). The low-polluting fuels program applies in cities of750,000 or more. • As of January of 1995, new emission standards and earlier model year urban bus engines that are rebuilt or replaced. Urban bus	Bus Demonstrations: • Urban Buses: The U.S. Department of Transportation (DOT) and DOE shall initiate cooperative ventures with local governments (in urban with populations of 100,000 or more) to cover the incremental costs of operating and purchasing buses using alternative fuels, including vehicle conversions. • School Buses: DOT may provide financial assistance to local units of government (in urban areas with populations of 100,000 or more) to cover the incremental costs of operating and purchasing buses using alternative fuels, including vehicle conversions.

	operators may choose between two options. Under the first option, at time of rebuild, an operator must install retrofit equipment that has been certified with EPA to achieve a specified cost. • Under the second option, an operator must replace the average PM emissions level of its urban bus fleet by a specified amount each year. The retrofit program will apply in cities with a 1980 population of 750,000 or more.	
Credits	For purchases of CFVs in advance of requirement or in excess of minimum requirement, by fleets not covered by mandates, or that meet more stringent emissions.	• Credits can be earned, at the rate of one credit per AFV, if AFVs are acquired in excess of minimum requirements or in advance of the requirement date. • If a state or alternative fuel provider acquires an AFV before model year1997, DOE will allocate one credit per AFV for each year the AFV is acquired before acquisition requirements apply. • States and alternative fuel providers may earn credits for the purchase of medium- and heavy-duty AFVs, only after they have fulfilled their light-duty AFV percentage requirement for that model year. Credits earned in this manner maybe used in subsequent model years. • Credits may be transferred from one area to anther and between any covered fleets. • See E.O. 13031 for Federal fleet credits for medium/heavy duty AFVs.
Incentives	FOR CFFP fleets, CFVs are exempt from time-based transportation control measures. CFVs that are certified as ILEV (inherently low-emission vehicle) are also exempt from high occupancy-vehicle (HOV) lane restrictions.	Deductions from adjusted gross income are provided as follows for the incremental costs of the engine, fuel storage, and delivery system, and exhaust/emissions control system of AFVs (including retrofits) and refueling facilities placed in service after June 30, 1993: • AFVs below 10,000 lb GVW: up to $2,000. • AFVs 10,000 - 26,000 lb GVW- up to $5,000. • Trucks/Vans (more than 26,000 lb GVW): up to $50,000. • Electric Vehicles: 10% tax credit up to $4,000/vehicle. • AFV Refueling Facility: up to $100,000. Only the incremental costs of the qualified items can be deducted for dual-or flexible-fuel vehicles.
Non-Road Engines	EPA is preparing to propose regulations to control emissions (oxides of nitrogen and PM) from heavy-duty (and other) engines used in non-road engines used in non-road applications, including farm equipment, marine engines and locomotives.	DOE is required to conduct a study to determine the effectiveness of using alternative fuels in non-road vehicles, such as rail, airport, seaport, and other vehicles.
Replacement Fuel	No provision.	The portion of a motor fuel that is methanol, ethanol, or other alcohol, CNG, LPG, hydrogen, coal-derived liquid fuel, fuel derived from biological materials, electricity and ethers. DOE may determine by rule that any other fuel that is "substantially not petroleum" and yielding "substantial energy security benefits and substantial environmental benefits" will qualify as a replacement fuel. • Petroleum reduction targets: By 2000: 10% replacement. By 2010: 30% replacement.
Exemptions	Vehicles that are exempt under the CFFP include the following: • Vehicles weighing more than 26,000 lb GVW; • Public leased or rented vehicles; • Vehicles for sale by dealers;	Under a proposed rule by DOE, exemptions can be provided if alternative fuels or AFVs are not available. Fuel is determined "available" if an alternative fueling or recharging station is within five miles of the fleet's operating range or base of operations.

	• Law enforcement vehicles; • Emergency vehicles; • Non-road vehicles; • Vehicles garaged at personal residences; and • Motor vehicles used for OEM testing.	AFVs are deemed "unavailable" if original equipment manufacturer(OEM) AFVs that meet normal requirements and practices of a covered fleet are not sold or leased anywhere in the United States. If OEM AFVs are available but cannot accommodate specific operating requirements and practices of the covered fleet, that fleet may qualify for an exemption under the proposed rule. Vehicles that are exempt include: • Public leased or rented vehicles; • Vehicles for sale by dealers; • Law enforcement vehicles; • Emergency vehicles; • Vehicles certified by the U.S. Secretary of Defense as exempt for national security reasons; • Non-road vehicles; and • Vehicles garaged at personal residences.
Fuel Definitions	Clean Alternative Fuels: Any power source on which a vehicle is certified to meet Federal CFV emission standards. This can be any fuel, including reformulated gasoline or conventional gasoline. For emission standards, contact EPA.	Alternative Fuels: • Methanol (M85) • Ethanol (E85) • Other alcohols, separately or in mixtures of 85% by volume or more (but no less than 70% by rule) with gasoline or other fuels. • Compressed Natural Gas • Liquefied Natural Gas • Liquefied Petroleum Gas (propane) • Hydrogen • Coal-derived fuels • Biofuels • Electricity or • Any other fuel that is substantially not petroleum and has substantial energy security and environmental benefits. ***Neither reformulated gasoline or conventional gasoline may be used to meet EPACT requirements.

Source: United States General Services Administration, Office of Government-wide Policy (OGP), http://policyworks.gov/org/main/mt/homepage/mtv/caaepact.htm.

Fleet-Specific Requirements Stipulated by EPAct:

DOE's Alternative Fuel Program, as mandated by the Energy Policy Act of 1992, currently applies to federal, state, and certain alternative fuel provider fleets. There is, however, a new rule being formulated and evaluated that will expand coverage to municipal and private fleets. In each case, the requirements apply to fleets of 20 or more vehicles that meet certain physical and use criteria and operate in a specified metropolitan area. A summary of the fleet-specific[68] requirements stipulated by EPAct follows:

[68] Fleet Types include: **Federal fleet -** One that is owned, operated, leased, or otherwise controlled by or assigned to any Federal executive department, military department, government corporation, independent establishment, or executive agency, the United States Postal Service, Congress, the courts of the United States, or the Executive Office of the President; **State fleet -** One that is owned, operated, leased or otherwise controlled by a state government or state agency. State means any of the 50 states, the District of Columbia, the Commonwealth of Puerto Rico, and any other territory or possession of the United States; **Fuel Provider fleet -** One that is owned, operated, leased or otherwise controlled by a "person" engaged in: importing, refining, or processing of crude oil to produce motor fuel; or importing, producing, storing, transporting, distributing, or selling motor fuel; or generating, transmitting, importing, or selling electricity at wholesale or retail.

1) **U.S. Federal Fleet** – EPAct specifies that at least 75 percent of the total number of light-duty vehicles acquired by a federal fleet each year shall be alternative fuel vehicles in fiscal year 1999 and thereafter.

2) **U.S. State Fleet** – Of the total number of light-duty vehicles acquired by state fleets each year, at least 25 percent shall be alternative fuel vehicles in vehicle model year 1999, at least 50 percent in vehicle model year 2000 and 75 percent in vehicle model year 2001 and thereafter.

3) **Fuel Provider** – EPAct specifies that at least 70 percent of the total number of light-duty vehicles acquired by alternative fuel provider fleets each year shall be alternative fuel vehicles in vehicle model year 1999 and 90 percent in vehicle model year 2000 and thereafter. A fuel provider fleet must comply with these requirements if the company meets the definition of "alternative fuel provider" and it operates at least 20 light-duty vehicles that meet the criteria described above.

4) **Municipal and Private Fleet** – Currently, municipal and private fleets (i.e., all fleets not covered as federal, state, or alternative fuel provider fleets) are NOT required to acquire AFVs. However, EPAct gave the DOE authority to expand coverage to include municipal and private fleets if it was deemed necessary to achieve the goals of EPAct. If fleet coverage is expanded, then EPAct specifies that, of the total number of light-duty vehicles acquired by municipal and private fleets each year, the following percentages shall be alternative fuel vehicles in vehicle model years specified:

2002	20%
2003	40%
2004	60%
2005	70%
2006	70%

DOE is currently following procedures to determine if fleet coverage should be expanded to include municipal and private fleets, although the outcome is uncertain at the time of this publication.

Appendix 2. Natural Gas Vehicle Projects to Reduce GHG Emissions Reported to the US 1605(b) Voluntary Greenhouse Gas Reporting Program

1999 NGV Projects Reported to the U.S. 1605(b)
Voluntary Reporting of Greenhouse Gases Program

(Note: The following project reports were pulled from the 1605(b) database. For more information and detail on project descriptions and emission calculations, contact the Voluntary Reporting Program at 1-800-803-5182 or infoghg@eia.doe.gov.)

Project Developer: Baltimore Gas & Electric Co.
Project Name: Alternatively Fueled Vehicles
Project Description:
Operation of various numbers of Alternatively-Fueled Vehicles using Compressed Natural Gas.

Estimation Method:
CO_2 comparisons are based upon DOE data indicating that the CO_2 emission coefficient for gasoline is 156.7 pounds of CO_2 per million BTU and the coefficient for natural gas is 117.1 pounds of CO_2 per million BTU (DOE EIA-1605(1998)). Assumed vehicles travel 15,000 miles per year and gasoline has a heating value of 115,400 Btu/gallon in an automotive application. Motor- gasoline vehicles have a fuel efficiency of approximately 288 mi/mmBtu and CNG vehicles have a fuel efficiency of 218 mi/mmBtu. Emissions are claimed for the CNG fuel consumed and reductions are claimed for the displaced motor gasoline.

	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Project Size: Vehicles				184	184	184	188	178	161
Reported Reductions (Metric Tons CO_2):				151.3	151.3	151.3	154.6	146.4	132.4

Project Developer: Central Hudson Gas & Electric Corporation.
Project Name: Natural Gas Vehicles
Project Description:
In 1988, several company fleet vehicles were converted to operate on natural gas with the ability to operate on gasoline retained. These conversions cost approximately $3,500 per vehicle. In addition, a 60cfm CNG station was constructed to refuel these vehicles. As the project continued, several more vehicles, mostly cars and light pick-up trucks, were converted, and new, factory built NGV`s were also purchased. Presently, 18 vehicles, including 4 factory built NGV`s purchased at a $3,500 premium over the gasoline versions, are being operated on natural gas.

Estimation Method:
The meters located at the sole NGV refueling site, record both the amount of natural gas delivered, plus the gasoline gallon-equivalent (a roughly 8.415 gallons/l,000 cubic feet conversion). The $C0_2$ emission rate (from Appendix B in the Form EIA-1605 Instructions) for natural gas (120.593 lbs/Mcf) was used to estimate the emissions from the CNG vehicles. The reference case emissions were calculated from the gasoline equivalent of the natural gas consumed using the emission rate for motor gasoline (19.564 lbs/gal). The latter emissions represent the emissions that would have occurred if the vehicles had been operated with gasoline.

1999 CO_2 Reduction Calculation:

Natural Gas: 766.6 Mcf (1999) x 120.593 lbs CO_2/MMBTU = 92,446.5938 lbs
92,446.5938 lbs/2,000 lbs per short ton = 46.2233 tons

Gasoline: 6,450.94 gal displaced (1999) x 19.564 lbs CO_2/MMBTU = 126,206.1906 lbs
126,206.1906 lbs/2,000 lbs per short ton = 63.10310 tons

Reduction: 63.1021 tons - 46.2233 tons = 16.8798 CO_2 ton reduction

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles		12	12	19	19	19	19	19	18
Reported Reductions (Metric Tons CO_2):	7.5	4.8	13.1	15.0	14.2	9.5	13.5	16.2	15.3

Project Developer: City of Palo Alto
Project Name: City fleet conversion to CNG
Project Description:
City fleet conversion to CNG: Total annual miles =168,040.
Total annual fuel = 17,566 therms.

Estimation Method:
City fleet conversion to CNG: Total annual miles =168,040.
Total annual fuel = 17,566 therms. Comparison made to average fleet car with 13 miles/gallon. Gallons saved are gross gallons saved, but CO_2 emission reduction is net of the CO_2 added by burning natural gas. Assumptions for Conversion to CO_2: 19.6 lbs/gallon of motor gasoline.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: number of CNG fueled vehicles									32
Reported Reductions (Metric Tons CO_2):									21.70

Project Developer: City Utilities of Springfield
Project Name: Natural Gas Fleet
Project Description:
City Utilities purchased one compressed natural gas service van for the use of our Telecommunications Department. In addition we installed a fueling station for this vehicle and others like it that we or others in our service territory may choose to purchase later. The van prominently advertises that it is an alternate fuel vehicle as it makes service calls throughout the territory.

City Utilities has previously indicated an intent to purchase one or more electric vehicles for this same purpose. The EV option is being reevaluated pending advancements in that technology and implementation in other parts of the country. In the meantime, the CNG alternate fuel vehicle will help introduce our constituents to alternate fuel options.

Estimation Method:
The emissions are all due to the natural gas burned at an emission rate of 120.593 lb CO_2 / Mscf.

The emission reduction is the difference between the gasoline that would have been emitted at 19.641 lb CO_2 / gal and the natural gas actually emitted.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles					1	1	1	1	1
Reported Reductions (Metric Tons CO_2):					0.8	0.7	1.1	0.7	0.5

Project Developer: Delmarva Power
Project Name: CNG Vehicles
Project Description:
Vehicles run on compressed natural gas (CNG) instead of gasoline. Beginning 1995, external fleets will also operate on natural gas. However, reductions reported in Part III reflect Delmarva Power's vehicles only.

Estimation Method:
For 1999:
CO_2 (tpy) = # CNG vehicles x (12,504 miles/yr)/(24 miles/gallon) x [19.6 lb CO_2/gal gasoline - (120.6 lb CO_2/mscf NG x 0.127 mscf NG/gal gasoline)]/2000 lbs/st)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles	5	11	21	31	28	43	37	36	31
Reported Reductions (Metric Tons CO_2):	7.3	16.3	30.8	45.4	40.8	62.6	53.5	52.6	31.8

Project Developer: Dynegy Midwest Generation Inc.
Project Name: CNG Vehicle Conversions
Project Description:
Since late 1992, Illinois Power has converted company-owned vehicles and work equipment to operate on compressed natural gas. Vehicles converted to CNG include passenger cars, light trucks, heavy-duty trucks and forklifts.

The volume of CNG consumed is listed in #4 above, as gallons. This is actually "gasoline gallon equivalent," or 5.66 lb of natural gas.

Estimation Method:
Total emissions were estimated by the difference between the emissions that would have resulted from the gasoline displaced, and from the emissions which resulted from the use of CNG. Actual gallons of CNG used by each vehicle type were multiplied by the fuel efficiency for each vehicle type to determine the mileage driven. The following assumptions were used for mileage estimates: cars 25 mpg, light duty trucks 15 mpg, and heavy duty trucks and forklifts 5 mpg. Gallons of CNG to gasoline equivalent were based on equal Btu values (125,000 Btu/gal). Emission factors for miles driven and for each fuel type were from Tables 4.2 and 4.3 in Vol. II of the "Guidelines" for reporting. Annual emissions were determined as follows:
Annual emissions=mileage x E factor per mile + fuel use x E factor per unit of fuel

Annual emissions were calculated for gasoline and for CNG and divided into direct and indirect emissions using 85% direct for gasoline and 81% direct for CNG. The difference from projected gasoline emissions and CNG emissions were reported as reductions.

* Previous years reductions were updated in 1996 to reflect the above assumptions and emission factors.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles			25	30	34	32	32	32	24
Reported Reductions (Metric Tons CO_2):	0.0	0.0	54.6	42.1	47.5	45.0	29.6	17.9	14.8

Project Developer: Entergy Services, Inc.
Project Name: Natural Gas Vehicle Program
Project Description:
The natural gas vehicles program began in Baton Rouge, La in 1981 and in New Orleans, LA in 1993.

Estimation Method:
The net CO_2 reductions from using natural gas instead of gasoline to fuel vehicles was calculated as follows:

CO_2 Emissions decreased (tons) = gasoline displaced (gallons) x 19.564 lbCO_2/gal x 1/2000 tons/lbs

CO_2 emission increase from use of natural gas(tons) = natural gas used (Mscf) x 120.593 lbCO_2/Mscf x 1/2000 tons/lb

Net CO_2 reductions = CO_2 Emissions decrease - CO_2 Emissions increase

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles	40	40	40	50	53	53	63	63	63
Reported Reductions (Metric Tons CO_2):	123.4	123.4	123.4	115.2	83.5	70.8	118.8	100.7	78.9

Project Developer: Niagara Mohawk Power Corporation
Project Name: Alternative Fuel Vehicles
Project Description:
NMPC has been involved in operating and testing alternative fuel vehicles (AFVs) for almost 30 years. The Company also currently has a number of "Clean Air" natural gas-fueled buses in operation as part of a cooperative program with the Syracuse, New York Centro transit system.

Estimation Method:
CO_2 emission reductions are based on the difference in CO_2 emissions between gasoline-fueled vehicles and CNG or electric vehicles. Only direct emission reductions are reported. Emissions estimates are based on a CO_2 emission factor for each fuel. For motor gasoline, an emission factor of 19.641 lbs/gallon was used. For diesel fuel, an emission factor of 22.384 lbs/gallon was used. For CNG vehicles, a factor of 120.593 lbs/Mcf was used. These factors are based upon Form EIA-1605, Voluntary Reporting of Greenhouse Gases, Instructions, Appendix B. Fuel and Energy Source Codes and Emission Coefficients: EIA, 1996. For electric vehicles, NYPPs marginal emissions rate of 1.44 lbs/kWh for the years 1991-1995, rate of 1.48 lbs/kWh for 1996, and 1.46 lbs/kWh for 1997 and 1998 were used. These marginal rates were determined based on production simulation modeling (PROMOD IV).

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles	9	11	19	24	52	50	44	37	28
Reported Reductions (Metric Tons CO_2):	1.9	4.3	10.8	12.6	28.2	24.3	22.6	20.1	16.6

Project Developer: NiSource/NIPSCO
Project Name: Natural Gas Vehicles
Project Description:
NIPSCO is committed to significantly increasing the percentage of NGVs in our fleet over the next several years through the following actions:
1) Purchasing factory-direct dedicated NGVs as available
2) Converting forklifts and light duty vehicles and trucks to compressed natural gas (CNG)
3) Utilizing liquefied natural gas (LNG) in our heavy-duty trucks

In addition to utilizing natural gas in our own fleet, NIPSCO will increase the number of NGVs operating throughout our region by providing a highly reliable fueling infrastructure, and by developing strategic alliances with educational, governmental, and social organizations. NGV training and consulting services will be provided to meet the mandates of the Clean Air Act Amendments of 1990. NIPSCO has been a leader in NGVs since 1981. The NGV market is expected to increase (in accordance with mandates contained in the Energy Policy Act of 1992). Market demands and preferences will then drive the further proliferation of NGVs through the end of this century.

Estimation Method:
NIPSCO used the following data below in its calculations.

Assumptions: for 1994-1998
CNG fuel usage rate = 46,886,000 cf/569 vehicles = 82,400 cf/vehicle
HHV gasoline 125,000 BTU/gal
HHV Natural Gas = 1030 BTU/cu.ft
Conversion Factor from NG to gasoline = (125,000 BTU/gal gas)(1 cu.ft. NG/1030 BTU)(1 BTU NG/0.94 BTU gas)
Conversion Factor from NG to gasoline = 129.1 cu.ft. NG/gallon of gasoline
Emission factors:
NG = 0.1206 lbs CO_2/cu.ft.
Gasoline = 19.64 lbs CO_2/gallon
Calculations:
Calc.1 (Number of CNG vehicles) x 82,400 cf/vehicle = cu.ft. NG
Calc.2 (cu.ft. of CNG) / 129.1 cu. ft. NG/gallon of gasoline = equiv. gallons of gasoline
Calc.3 (cu.ft. NG) x 0.1206 lbs CO_2/cu.ft./2000 = tons CO_2 from NG
Calc.4 (gallons of gasoline) x 19.641 lbs CO_2/cu.ft./2000 = tons CO_2 from gasoline
Calc.5 Difference between NG CO_2 and gasoline CO_2

For 1999 NiSource implemented an automated fuel tracking system and was able to more accurately report the amount of GGE (Gallons of Gasoline Equivalent) used throughout our service territory.

Year	GGE	CO_2 Emissions (Tons)	CO_2 Reductions (Tons)
1999	242,888	1,772	604

1 GGE (gallon of Gasoline Equivalent) x 121 = cu ft NG
NG = 120.593 lbs CO_2/1000 cu ft
1 GGE CO_2 emission rate = 1 GGE*121*120.593 lbs CO_2/1000 cu ft = 14.59 lbs CO_2/GGE
1 Gallon of Gasoline CO_2 emission rate = 19.564 lbs CO_2/gallon gasoline
Savings = 19.564 - 14.59 = 4.974 lbs CO_2/GGE

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles		704	645	569	610	630	599	607	618
Reported Reductions (Metric Tons CO_2):	818.3	820.1	752.1	663.2	711.2	733.9	698.5	707.6	550.7

Project Developer: PG&E Corporation
Project Name: Natural Gas Vehicles
Project Description:
Pacific Gas and Electric Company Clean Air Vehicle Program: In 1990 Pacific Gas and Electric Company received California Public Utility Commission approval to spend up to $50 million by December 31, 1994 to support the development and introduction of electric and natural gas vehicles. By the end of 1993, Pacific Gas and Electric Company was operating 698 natural gas vehicles and 30 natural gas refueling stations. Encouragement took many forms: demonstrating vehicle and station performance, providing natural gas refueling station designs, providing partial funding for vehicle purchases, opening Company stations for public use, etc. After 1994, there was a decreased emphasis on customer financial support. But Pacific Gas and Electric Company has continued to promote, facilitate and encourage electric and natural gas vehicle use by its customers. Pacific Gas and Electric Company continues to claim credit for not only its own fuel displacement, but also for displacements that it has encouraged its customers to undertake.

Estimation Method:
Natural gas therms used by natural gas vehicles is estimated from meter records of natural gas delivered by Pacific Gas and Electric Company to its own natural gas vehicle refueling stations, and of the natural gas supplied to customer owned natural gas refueling stations within its service territory. Pacific Gas and Electric Company takes credit for natural gas savings by customers within the Company's northern and central California service territory because Pacific Gas and Electric Company ratepayers funded a comprehensive program to promote natural gas use in vehicles, which program included both financial and technical support for numerous customer stations. Using the following factors, the Company calculates CO_2 emissions and emissions avoided through displaced gasoline:
103,001 mmBtu per million therms
1.1 therms per equivalent gallon of gasoline
117.08 lbs. CO_2 per mmBtu natural gas
19.564 lbs. CO_2 per gallon of gasoline

In 1999 a total of 7.065 million therms of natural gas were used to displace gasoline.
62,827 tons CO_2 gasoline - 42,599 tons CO_2 natural gas = 20,228 tons CO_2 avoided.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles				698	873	820	828	696	633
Reported Reductions (Metric Tons CO_2):				7,455.2	9,667.0	12,293.3	15,648.0	16,623.3	18,350.5

Project Developer: Portland General Electric Co.
Project Name: Natural Gas Fleet Vehicles
Project Description:
These are fleet vehicles voluntarily converted to natural gas. They operate in PGE`s service area and commute to generation facilities. This area is the northern Willamette Valley and Columbia River gorge.

Estimation Method:
We know that 2 vehicles were converted in 1993 and 4 additional vehicles were converted in 1994. Fifteen more natural gas vehicles were delivered in mid-year (June) 1997. In 1998 eight 1/2 ton pickups were converted allow natural gas as a fuel in mid-year 1998. In 1999, another ten 1/2 ton pickups were converted to allow natural gas as a fuel in mid year 1999. We assume the fleet vehicles travel 8000 mi/year each, that the gasoline mileage is 20 mi/gal, and that each gasoline vehicle emits 7838 pounds of CO_2 per year and each NG vehicle emits 4752 pounds per year. Fuel use for the NG vehicle was estimated using a conversion of 118 pounds of CO_2 per MBTU of energy.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicle Miles Traveled			16,000	48,000	48,000	48,000	108,000	200,000	272,000
Reported Reductions (Metric Tons CO_2):			2.8	8.4	8.4	8.4	18.9	35.0	47.6

Project Developer: Public Service Company of New Mexico
Project Name: CNG Vehicles
Project Description:
PNM has been increasing the use of CNG vehicles in its fleet, particularly for its cars and small trucks and vans. In the twelve-month period ending 6/30/97, PNM vehicles logged nearly 24 million miles. Of this amount, CNG-capable vehicles logged 4,082,778 miles, of which approximately 90% of these miles were fueled by CNG (the balance were fueled by unleaded gasoline as the vehicles are dual fueled). Since CNG is a lower carbon fuel than is gasoline, approximately 40 pounds of CO_2 are saved for each MMBtu of gasoline displaced. This is based on emission factors of 157.041 lbs CO_2/MMBtu for motor gasoline and 117.080 lbs CO_2/MMBtu for natural gas.

1997:
In the period 7/1/97 through 5/31/98, PNM fleet vehicles logged approximately 13 million miles. Of this amount, CNG-capable vehicles logged 1,964,763 miles of which approximately 75% of these miles were fueled by CNG (the balance were fueled by unleaded gasoline as the vehicles are dual fueled). Since CNG is a lower carbon fuel than gasoline, approximately 41.4 pounds of CO_2 are not released for each MMBtu of gasoline displaced. This is based on emission factors of 156.662 lb CO_2/MMBtu for motor gasoline and 115.258 lb CO_2/MMBtu for natural gas (1998 Instructions for Form EIA-1605, Appendix B).

1998:
Since the last reporting period, PNM fleet vehicles logged approximately 11.9 million miles. Of this amount, CNG-capable vehicles logged 1,355,833 miles. Since CNG is a lower carbon fuel than gasoline, approximately 41.167 pounds of CO_2 are not released for each MMBTU of gasoline displaced. This is based on emission factors of 156.425 lb CO_2/MMBTU for motor gasoline and 115.258 lb CO_2/MMBTU for natural gas (1999 Instructions for Form EIA -1605, Appendix B).

1999:
Data not available

Estimation Method:
1996
The CO_2 savings of using the CNG vehicles were estimated as follows:
4,082,778 miles in CNG vehicles x 90% of those miles are CNG fueled = 3,674,500 CNG miles
3,674,500 CNG miles / 12 miles per gallon equivalent = 306,208.33 gallons equivalent of CNG used
306,208.33 gallons equivalent of CNG used / 8.08 gallons of gasoline per MMBtu (5.2 MMBtu/bbl.gasoline)= 37,897.071 MMBtu of CNG used
37,897.071 MMBtu of CNG used x 40 lbs.CO_2 saved per MMBtu of CNG used instead of gasoline = 1,515,883 lbs. of CO_2 saved
1,515,883 lbs. of CO_2 saved / 2000 lbs. per ton = 757.941 tons of CO_2 saved

1997

The CO_2 savings are estimated as follows:

1964763 miles in CNG vehicles x 75% of those miles CNG-fueled = 1,473,572 CNG miles

1,473,572 CNG miles / 12 miles per gallon equivalent = 122,798 gallons equivalent of CNG used

122,798 gallons equivalent of CNG used / 8.08 gallons per MMBtu = 15,198 MMBtu of CNG used

15,198 MMBtu of CNG used x 41.4 lb CO_2 saved per MMBtu (see note below) = 629,197 lb of CO_2 not emitted

629,197 lb of CO_2 not emitted / 2000 = 314.6 tons CO_2 not emitted

NOTE: MG = 156.662 lb CO_2/MMBtu

CH4= 115.258 lb CO_2/MMBtu

MG-CH4 = 41.4 lb CO_2/MMBtu

1998

The CO_2 savings are estimated as follows:

1,355,833 miles in CNG vehicles / 12 miles per gallon equivalent = 112,986 gallons equivalent of CNG used

112,986 gallons equivalent of CNG used / 8.08 gallons per MMBtu = 13,983 MMBTU of CNG used

13,983 MMBTU of CNG used x 41.167 lb CO_2 saved per MMBTU (see note below) = 575,638 lb CO_2 not emitted

575,638 lb CO_2 not emitted / 2000 = 287.8 tons of CO_2 not emitted

NOTE: MG = 156.425 lb CO_2/MMBTU

CH4 = 115.258 lb CO_2/MMBTU

MG-CH4 = 41.167 lb CO_2/MMBTU

The first set of available calculations is for 1996.

1999 - Data not available

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicle Miles Traveled						3,674,500	1,473,572	1,355,833	
Reported Reductions (Metric Tons CO_2):						687.6	285.8	261.3	

Project Developer: Tennessee Valley Authority
Project Name: Alternate Fuel Vehicles
Project Description:
In 1994, TVA had 31 alternate fuel vehicles operating in its transportation fleet. These included 23 sedans fueled by M-85 (a blend of 85% methanol and 15% gasoline), 2 compressed natural gas vans, 5 electric pickup trucks, and one electric van.

In question 4, the alternate fuel type listed as "ZZ" is the M-85.

Project results for 1995, 1996, 1997, 1998 and 1999 are not reported, as data were not available.

Estimation Method:
The direct emissions shown in Part 3 are the emissions used to compute the reported emissions reductions. These are the total emissions from the TVA transportation fleet. The actual CO_2 emissions were determined from the fuel consumed and the fuel emissions factor from Appendix B. See the previous project, Transportation Fleet Fuel Efficiency Improvements.

The CO_2 reductions as a result of alternate fuel vehicle (AFV) operation is the net difference between the modified reference case CO_2 emissions and the actual emissions from the AFVs. The modified reference case emissions are the emissions that would have occurred had the miles driven by the AFVs been driven by the conventional fleet. The modified reference case emissions were determined from the actual AFV miles traveled, the average miles per gallon for the comparable conventional vehicles, the heating value of gasoline (125,100 BTU/Gal), and the gasoline emissions factor from Appendix B (157 lb CO_2/MM BTU). It was assumed that the electric and CNG vehicles displaced emissions from the conventional 4X2 pickup fleet and the M-85 vehicles displaced emissions from the conventional sedan fleet.

The actual emissions for the CNG and M-85 AFVs were determined from the fuel usage, the heating value of the fuel, and the fuel emissions factor. The heating value for CNG is 1000 BTU/Ft3 and for M-85 is 73,590 BTU/Gal. The emissions factor for CNG is 120 lbs CO_2/MM BTU and 146 lbs CO_2/MM BTU for M-85.

To determine the actual emissions for the electric vehicles it was assumed that the energy used to charge the vehicles was generated by the TVA coal fired system. The emissions associated with the charging was determined from the KWH used, the average coal fired system heat rate, and the coal emissions factor from Appendix B.

The following table summarizes the operation of the AFVs and the resulting effect on CO_2 emissions for 1994. In this table, negative changes, i.e. reductions, are shown in parentheses.

Alt. Fuel	Change in Miles Driven	Alt. Fuel Used	Conv. Vehicle MPG	Change in Gasoline Gallons	Conv. Vehicle CO_2 Tons	Heat Rate BTU/ Kwh	Fossil Fuel CO_2 Tons	Change In CO_2 Emission Tons
M-85	14,258	544 Gal	29.8	(478)	(4.7)	-----	2.9	(1.8)
CNG	1,301	25,000 CF	15.5	(84)	(0.8)	-----	1.5	0.7
Elec.	4,201	1,360 Kwh	21.2	(198)	(1.9)	10,047	1.4	(0.5)
Total	19,760			(760)	(7.5)		5.8	(1.6)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicle Miles Traveled				19,760					
Reported Reductions (Metric Tons CO_2)				1.5					

Project Developer: TXU
Project Name: Alternative Fuel Vehicle Program
Project Description:
TXU operates a fleet of alternatively fueled vehicles (chiefly compressed natural gas). This is the fourth year that the Company has included the carbon dioxide emissions reductions from these vehicles in the Climate Challenge Program.

Estimation Method:
Estimates of the reduction of carbon dioxide from operating alternative fueled vehicles were based on the assumption that equivalent miles would have been driven by gasoline powered vehicles. First, the equivalent tons of carbon dioxide from gasoline vehicles were calculated then this quantity was subtracted from the equivalent tons of carbon dioxide generated from alternative fueled vehicles driving the same number of miles. Emission factors for carbon dioxide per fuel type were taken from Tables 4.2 and 4.3, page 4.19 of the Sector-Specific Issues and Reporting Methodologies, Volume II, part 4- Transportation Sector, October 1994. The DOT CAFE Standard of 27.5 mpg divided by 1.15 was used as the miles per gallon of gasoline and 20 mpg divided by 1.15 for propane was estimated.

The emission factors used for this project are listed:

	Direct	Indirect	Total
Gasoline	8,900	2,100	11,000 g/gal
Propane	5,747	483	6,230 g/gal
Methane	60.5	3.9	64.4 g/ft3

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles						323	300	300	266
Reported Reductions (Metric Tons CO_2)						592.4	483.5	517.1	445.4

Project Developer: Volvo Cars of North America, Inc.
Project Name: CNG Bi-fuel Test Fleet
Project Description:
Volvo's Bi-Fuel Compressed Natural Gas (CNG) Vehicle Test Fleet program investigation began in 1995 and culminated in 1996 with the construction of an on-site quick fill CNG vehicle refueling station to support our test fleet. This station represents a major investment and indicates our dedication to the long-term success of the test program. The valuable knowledge gained through implementation of this program, will enable Volvo to provide this type of vehicle for sale provided the necessary infrastructure to support the required vehicle refueling capabilities are in place.

Estimation Method:
Emission reduction calculations incorporating the offsetting emissions from the combustion of natural gas are as follows: (4676 gal * 19.6 lbs CO_2/gal) - (576.4 Mscf * 120.6 lbs CO_2/Mscf) = 22136 lbs.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Cars									20
Reported Reductions (Metric Tons CO_2):									10.04

Project Developer: Western Resources, Inc.
Project Name: Conversion of Company Fleet Vehicles to Alternative Fuels
Project Description:
Conversion of Company Fleet Vehicles to Alternative Fuel Vehicles - Western Resources has converted company fleet vehicles to compressed natural gas (CNG) or dual fuel (CNG and gas/diesel) vehicles. These alternative fuel vehicles emit approximately 1/2 of the equivalent CO_2 emissions as conventional vehicles. Western Resources currently has 5 alternative fuel vehicles (AFV).

Estimation Method:
(1) Western Resources has converted the following fleet vehicles to alternative fuel vehicles:

1991 CNG Vehicles - 0	1991 Dual Fuel Vehicles - 3
1992 CNG Vehicles - 6	1992 Dual Fuel Vehicles - 20
1993 CNG Vehicles - 6	1993 Dual Fuel Vehicles - 15
1994 CNG Vehicles - 9	1994 Dual Fuel Vehicles - 16
1995 CNG Vehicles - 2	1995 Dual Fuel Vehicles - 22
1996 CNG Vehicles - 2	1996 Dual Fuel Vehicles - 22
1997 CNG Vehicles - 2	1997 Dual Fuel Vehicles - 22 (Jan. to Nov.1997)
11/97 CNG Vehicles - 1	1997 Dual Fuel Vehicles - 4 (December 1997)
1998 CNG Vehicles - 1	1998 Dual Fuel Vehicles - 4
1999 CNG Vehicles - 1	1999 Dual Fuel Vehicles - 4

In November 1997, 19 AFVs were transferred to OneOak, with the remaining 5 APVs being retained by Western Resources (1 CNG and 4 Duel Fuel).

(2) Based on information available from Argonne National Laboratories studies, the overall equivalent CO_2 emissions reduction of a CNG vehicle compared to a conventional vehicle is approximately 1.05 metric tons annually. This includes the net effect of an equivalent reduction in N2O emissions and an equivalent increase in CH4 emissions. This emissions data was also summarized in the 1605(b) transportation guidelines. It is assumed company vehicles are used for 10,000 vehicle miles traveled (VMT) per year on average.

(3) Assuming dual fuel vehicles are operated on CNG 75% of the time and therefore, reduce equivalent emissions by 75% of a dedicated CNG vehicle, the equivalent CO_2 emissions avoided are estimated as:
1991 Equiv. CO_2 Emissions Avoided = 2 metric tons
1992 Equiv. CO_2 Emissions Avoided = 22 metric tons
1993 Equiv. CO_2 Emissions Avoided = 18.1 metric tons
1994 Equiv. CO_2 Emissions Avoided = 22.1 metric tons
1995 Equiv. CO_2 Emissions Avoided = 19.4 metric tons
1996 Equiv. CO_2 Emissions Avoided = 19.4 metric tons
1997 Equiv. CO_2 Emissions Avoided = 18.2 metric tons
1998 Equiv. CO_2 Emissions Avoided = 4.2 metric tons
1999 Equiv. CO_2 Emissions Avoided = 4.2 metric tons

(4) Future CO_2 emissions avoided were based on a continuation of the 4.2 metric tons in the future for the two years covering 1999-2000.

(5) No indirect emissions impacts were estimated.

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles	2.25	21	17.3	21	18.5	18.5	17.3	5	5
Reported Reductions (Metric Tons CO_2):	2.0	22.0	18.1	22.1	19.4	19.4	18.2	4.2	4.2

Project Developer: Wisconsin Electric Power Co.
Project Name: Vehicle conversion to dual fuel capability
Project Description:
Conversion of gasoline-fueled vehicles to dual fuel capability (gasoline and Compressed Natural Gas or CNG) reduces CO_2 emissions while the vehicle is using CNG. WE also has a Vehicle CNG Program in which they provide technical assistance to customers wishing to utilize CNG vehicles. Assistance includes: an assessment of how clean fuel legislation and requirements affect the customers business; identification of available technology; determination of the suitability of the customers fleet for conversion; calculation of the cost of the conversion; determination of operating cost savings; determination of fueling station requirements; calculation of payback; and acquisition of bids from conversion equipment vendors. WE will assist in facilitating cooperation between groups who may wish to share the cost of refueling equipment. WE also has a custom spreadsheet to evaluate rebate incentives for larger fleets. In addition, WE provides incentives to encourage conversion of customers vehicles and WE employees personal vehicles to CNG. These incentives include a rebate of $500 or $0.50 per annual therm, whichever is greater, for each vehicle converted up to two vehicles; available financing (at 0% interest for WE employees); and fueling availability at WE fueling stations. System CO_2 emission reductions due to CNG vehicle conversions in baseline years (in tons):

Year	1987	1988	1989	1990
Tons	94	89	55	49

Estimation Method:

Data Source: Form 1605(b) instruction manual

CO_2 Emission Reductions = CO_2 (gasoline saved) - CO_2 (natural gas used) = (gal. gasoline * emission factor) - (mscf * emission factor)
Direct reductions are related to conversion of company vehicles. Indirect reductions are related to conversion of customer vehicles.

NOTE: 1998 and revised 1997 values reflect the unavailability of CNG conversion kits for WE fleet vehicles plus an error in calculation that had resulted in understating total 1997 CO_2 emission reductions by about 700 st. Emission rates were revised for 1995 through 1998 in 10/99.

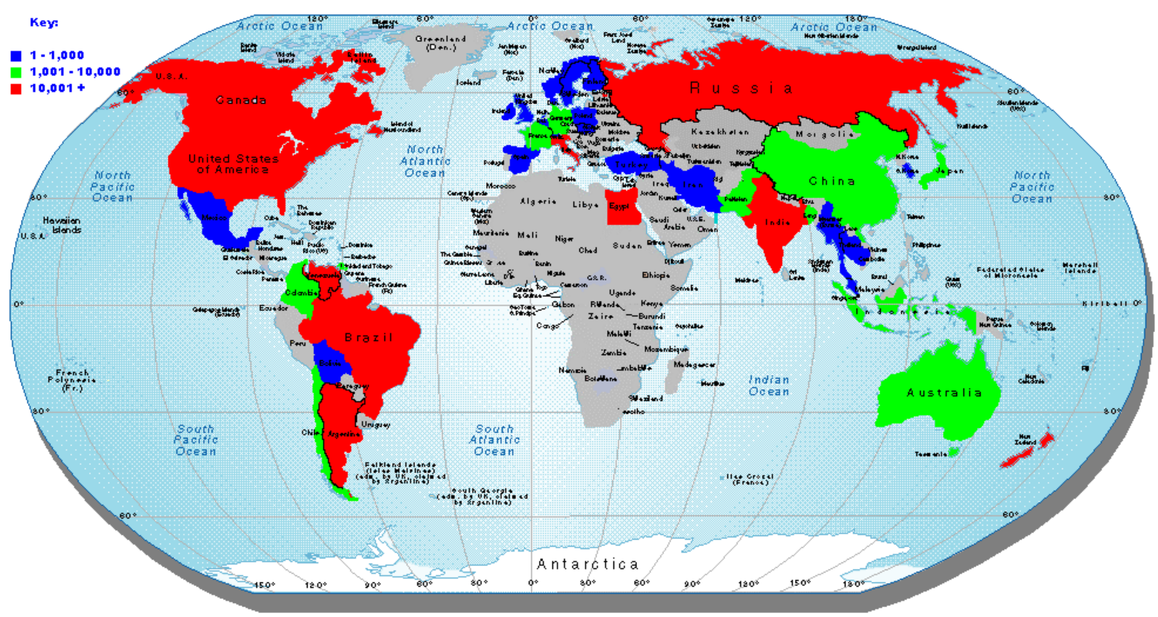
	1991	1992	1993	1994	1995	1996	1997	1998	1999
Project Size: Vehicles	47	130	224	335	524	538	652	828	688
Reported Reductions (Metric Tons CO_2):	175.0	598.0	1,118.0	1,505.9	2,360.1	2,417.3	2,926.7	3,646.0	3,076.3

Appendix 3. International Use of NGVs

As stated in Chapter 1.6, Current Trends in Deployment of NGVs, there are more than one million natural gas cars, trucks, and buses operating worldwide, with nearly 4,000 refueling stations to support the vehicles. The vast majority of these vehicles are located in Argentina, Italy, the United States, Brazil, Russia, Venezuela, and Canada. Argentina leads the world with more than 400,000 NGVs followed by Italy with over 300,000, the United States with approximately 104,000 and Brazil with 60,000. Although the United States ranks third in terms of numbers of NGVs, it ranks first in the world in total number of refueling stations with over 1,200 nationwide. NGV technology is not new to the world. Italy has been using natural gas as a vehicle fuel since the 1920s. In the United States, NGVs have been in use since the 1960s and NGVs played an important role in the former Soviet Union's vehicle fleets. Moreover, countries such as Canada and Venezuela have national programs that provide assistance for vehicle conversion and refueling stations.

There are many U.S. companies that are heavily involved in NGV development internationally. The list includes Deere Power Systems Group, Cummings Engines, Natural Gas Vehicle Company, Dyntech Industries Inc., Thomas Built Buses, NGV EcoTrans, Pressed Steel Tank Company, Blue Energy Inc., and Hurricane Compressors.

Figure A1. Worldwide Distribution of NGVs



NGV Countries of the World

Source: International Association for Natural Gas Vehicles http://www.iangv.org/html/ngv/stats.html.

Table A2. International NGV Statistics for Vehicles Counted as of August 2000

Country	Vehicles Converted	Refueling Stations
Argentina	462,186	830
Italy	320,000	320
United States	90,000	1,250
Brazil	60,000	55
Russia	30,000	208
Venezuela	27,542	151
Canada	20,505	222
Egypt	19,000	35
New Zealand	12,000	100
India	10,000	11
China	6,000	70
Japan	5,684	107
Germany	5,000	110
Bolivia	4,860	17
Colombia	4,500	22
Pakistan	4,000	30
Trinidad & Tobago	4,000	12
Malaysia	3,700	17
France	3,309	105
Indonesia	3,000	12
Chile	2,000	5
Sweden	1,500	22
Australia	1,000	35
Mexico	1,000	5
Bangladesh	1,000	5
Great Britain	835	18
Iran	800	2
Holland	574	27
Spain	300	6
Belgium	300	5
Switzerland	270	14
Burma	200	
Turkey	189	3
Austria	83	5
Thailand	82	1
Ireland	65	1
Finland	34	5
Czech	30	11
Nigeria	28	2
Luxembourg	25	5
South Korea	22	1
Poland	20	4
Norway	18	3
Denmark	5	1
Korea	4	1
Algeria		1
Totals	1,105,670	3,872

Source: International Association for Natural Gas Vehicles http://www.iangv.org/html/ngv/stats.html.

Appendix 4. U.S. Initiative on Joint Implementation (USIJI) Project Criteria

Criteria from the Final USIJI ground rules as published in the Federal Register on June 1, 1994:

"Section V—Criteria

A. To be included in the USIJI, the Evaluation Panel must find that a project submission:

(1) Is acceptable to the government of the host country;
(2) Involves specific measures to reduce or sequester greenhouse gas emissions initiated as the result of the U.S. Initiative on Joint Implementation, or in reasonable anticipation thereof;
(3) Provides data and methodological information sufficient to establish a baseline of current and future greenhouse gas emissions:
(a) In the absence of the specific measures referred to in A.(2)-- of this section; and
(b) As the result of the specific measures referred to in A.(2) of this section;
(4) Will reduce or sequester GHG emissions beyond those referred to in A.(3)(a) of this section, and if federally funded, is or will be undertaken with funds in excess of those available for such activities in fiscal year 1993;
(5) Contains adequate provisions for tracking the GHG emissions reduced or sequestered resulting from the project, and on a periodic basis, for modifying such estimates and for comparing actual results with those originally projected;
(6) Contains adequate provisions for external verification of the greenhouse gas emissions reduced or sequestered by the project;
(7) Identifies any associated non-greenhouse gas environmental impacts/benefits;
(8) Provides adequate assurance that greenhouse gas emissions reduced or sequestered over time will not be lost or reversed; and Provides for annual reports to the Evaluation Panel on the emissions reduced or sequestered, and on the share of such emissions attributed to each of the participants, domestic and foreign, pursuant to the terms of voluntary agreements among project participants.

B. In determining whether to include projects under the USIJI, the Evaluation Panel shall also consider:

(1) The potential for the project to lead to changes in greenhouse gas emissions elsewhere;
(2) The potential positive and negative effects of the project apart from its effect on greenhouse gas emissions reduced or sequestered;
(3) Whether the U.S. participants are emitters of greenhouse gases within the United States and, if so, whether they are taking measures to reduce or sequester such emissions; and
(4) Whether efforts are underway within the host country to ratify or accede to the United Nations Framework Convention on Climate Change, to develop a national inventory and/or baseline of greenhouse gas emissions by sources and removals by sinks, and whether the host country is taking measures to reduce its emissions and enhance its sinks and reservoirs of greenhouse gases."

Bibliography

Activities Implemented Jointly Uniform Reporting Format: Activities Implemented Jointly under the Pilot Phase, The RABA/IKARUS Compressed Natural Gas Engine Project, http://www.unfccc.int/program/aij/aijact/hunnld01.html

Agee, Mark A., "Economic Gas To Liquids Technologies – A New Paradigm for the Energy Industry." Paper presentation at *Montreux Energy Roundtable VIII*, Montreux, Switzerland, May 12-14, 1997, http://www.syntroleum.com/pdfs/montreux597.pdf

Agee, Mark A., "Fuels for the Future." Paper presentation at *Energy Frontiers International Conference, Gas Conversion: Projects, Technologies, & Strategies*. San Francisco, CA October 20-22, 1999, http://www.syntroleum.com/pdfs/sf_1099.pdf

Agee, Mark A., "GTL vs. Low Oil Prices – The Insulating Factors." Paper Presentation at *Monetizing Stranded Gas Reserves '98 Conference.* San Francisco, CA, December 14-16, 1998, http://www.syntroleum.com/pdfs/sf_1298.pdf

Alternative Fuels Data Center, http://www.afdc.nrel.gov/

Alternative Fuel Transportation Program, final rules, http://www.afdc.doe.gov/pdfs/fprovrule.pdf

American Automobile Manufacturers Association (AAMA), *World Motor Vehicle Data 1993*. Washington, D.C., 1993

American Automobile Manufacturers Association (AAMA), *Motor Vehicle Facts and Figures 1996.* Washington, D.C., 1996

Bechtold, Rich, "Is Clean Diesel Fuel and Option for Chile?" Paper Presented at the International Seminar: *Public Transport, Natural Gas, and the Environment: Challenges for 2000*. Santiago, Chile, May 22-24, 2000

California Energy Commission, "NGV–Fuel and Vehicle History and Characteristics," http://www.energy.ca.gov

Chomitz, Kenneth M., "Baselines for Greenhouse Gas Reductions: Problems, Precedents, Solutions," Draft Paper. World Bank, Washington D.C., July 1998

Clark, Wendy, *et al*, "Overview of Diesel Emission Control—Sulfur Effects Program." SAE Paper 2000-01-1876 Presented at the *CEC/SAE International Spring Meeting.* Paris, France, June 19-22, 2000

The Clean Air Act as Amended in 1990, http://www.epa.gov/oar/caa/contents.html

The Climate Change Action Plan, President William J. Clinton , October, 1993 http://www.gcrio.org/USCCAP/toc.html

Doherty, Julie and Jette Findsen, "Case Study: CNG Taxis, The Republic of Clean Cities." Presentation for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies*. San Diego, CA, May 10, 2000

Electric Vehicle Association of Canada, "Full Fuel Cycle Emission Reductions Through the Replacement of ICEVs with BEVs." July 10, 2000

Energy Information Administration, *Alternatives to Traditional Transportation Fuels 1998*, http://www.eia.doe.gov/cneaf/solar.renewables/alt_trans_fuel98/atf_99.html

Energy Information Administration, *Monthly Energy Review,* Table 9.4, Washington, DC, 2000

Energy Information Administration, *Natural Gas Annual*, *1999*, Table 95, Washington, DC, 2000

Energy Policy Act of 1992, Title V – Availability And Use Of Replacement Fuels, Alternative Fuels, And Alternative Fueled Private Vehicles, Section 502, http://energy.nfesc.navy.mil/docs/law_us/92epact/hr_0500.htm

Energy Policy Act of 1992, Title XVI - Global Climate Change, http://energy.nfesc.navy.mil/docs/law_us/92epact/hr_1600.htm

"EPA Dramatically Reduces Pollution From Heavy-Duty Trucks and Buses; Cuts Sulfur Levels in Diesel Fuel," Press Release, U.S. Environmental Protection Agency (EPA). Washington, DC, December 21, 2000. http://www.epa.gov

"Good Practice Greenhouse Abatement Policies: Transport Sector," OECD and IEA Information Papers prepared for the Annex I Expert Group on the UNFCCC. OECD and IEA, Paris, November 2000

Hargrave, Tim, *et al*, "Options for Simplifying Baseline Setting for Joint Implementation and Clean Development Mechanism Projects." Center for Clean Air Policy, Washington, D.C., November 1998

Intergovernmental Panel on Climate Change, *The Science of Climate Change, Contribution of Working Group I to the Second Assessment of the Intergovernmental Panel on Climate Change.* Cambridge University Press, United Kingdom, 1996.

International Association for Natural Gas Vehicles, "International Natural Gas Vehicle Statistics 2000 Online," http://www.iangv.org/html/ngv/stats.html

International Association for Natural Gas Vehicles, http://www.iangv.org/html/sources/qa.html#meet

The Kyoto Protocol to the United Nations Framework Convention on Climate Change, http://www.unfccc.de/resource/docs/convkp/kpeng.html

McCarthy, James and Sean Turner, "Natural Gas Vehicles and Greenhouse Gas Emissions." Presentation for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies.* San Diego, CA, May 10, 2000

Natural Gas Vehicle Coalition (NGVC), *1999-2000 Natural Gas Vehicle Purchasing Guide*, http://www.ngvc.org

Pacific Northwest Pollution Prevention Center (PPRC), "Alternative Fuels for Fleet Vehicles," http://www.pprc.org

Pianin, Eric. "U.S. Aims to Pull out of Warming Treaty: 'No Interest' in Implementing Kyoto Pact, Whitman Says." *Washington Post*, Wednesday, March 28, 2001

United Nations Framework Convention on Climate Change (UNFCCC), http://www.unfccc.int/resource/conv/conv_002.html

United Nations Framework Convention on Climate Change, Activities Implement Jointly Website, http://www.unfccc.de/program/aij/aijproj.html

U.S. Department of Energy. *Alternative Fueled Vehicles for State and Fuel Provider Fleets: A Guide for Meeting the Requirements of the Alternative Fuel Transportation Program.* http://www.afdc.doe.gov/pdfs/newguid.pdf

U.S. Department of Energy, Clean Cities Website, http://www.ccities.doe.gov

U.S. Department of Energy, Clean Cities Website, “What is an HEV?” http://www.ott.doe.gov/hev/what.html

U.S. Department of Energy, Clean Cities Website**.** *U.S. Federal Incentives and Regulations Affecting the Use of NGVs.* http://www.fleets.doe.gov/fleet_tool.cgi?$$,benefits

U.S. Department of Energy, *DOE Fossil Energy Techline*, “University of Alaska-Fairbanks to Lead University, Industry Team, in Department of Energy Project to Develop ‘Gas-to-Liquids’ Technology,” April 16, 1999, http://www.fe.doe.gov/techline/tl_akgastoliq.html

U.S. Department of Energy, Office of Transportation Technologies, “EPACT/Clean Fuel Fleet Program Fact Sheet,” http://www.afdc.doe.gov/pdfs/caaa.pdf

U.S. Department of Energy, Office of Transportation Technology, ATA Foundation, Alternative Fuels Task Force, “Alternative Fuels Tax Guide for 1999,” http://www.afdc.doe.gov/documents/fed-tax.html

U. S. General Services Administration, Office of Government-wide Policy (OGP), http://policyworks.gov/org/main/mt/homepage/mtv/caaepact.htm

U.S. Initiative on Joint Implementation, *Resource Document on Project & Proposal Development under the U.S. Initiative on Joint Implementation*. Version 1.1, June 1997

Voluntary Reporting of Greenhouse Gases Program, U.S. Department of Energy, Energy Information Administration, http://www.eia.doe.gov/oiaf/1605/frntvrgg.html

Wang, Michael Q., “Fuel-Cycle Analysis of Transportation Fuels: Development and Use of the GREET Model.” Presentation for the NETL-sponsored training session, *Developing International Greenhouse Gas Emission Reduction Projects Using Clean Cities Technologies*. San Diego, CA, May 10, 2000

Wang, Michael Q., *GREET 1.5 – Transportation Fuel-Cycle Model: Volume 1 Methodology, Development, Use and Results*. Argonne National Laboratory, August 1999

Wisconsin Department of Natural Resources, http://www.dnr.state.wi.us/org/aw/air/reg/cff/cff.htm

World Bank, Prototype Carbon Fund (PCF*)*, PCF Fund Management Team presentation at SBSTA 13, Lyon, France, September 2000, http://www.prototypecarbonfund.org

World Resources Institute, *Proceed With Caution: Growth in the Global Motor Vehicle Fleet*, http://www.wri.org/trends/autos.html